A GEOSPATIAL AND ECONOMIC ANALYSIS OF POTENTIAL FOR AFFORESTATION IN CANTERBURY, NEW ZEALAND

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ABSTRACT

Canterbury's plantation forest area has been declining due to land use change. The future size of the forestry industry is uncertain and without afforestation is predicted to be significantly smaller. A reduction in the plantation forestry area will reduce available log supply which will negatively impact local domestic processors.

To explore the opportunities for future afforestation, this study identifies land within Canterbury deemed suitable for forestry. The land deemed suitable for forestry within the Hurunui Territorial Authority (TA) was further evaluated to identify the land where forestry is economically superior to the next best alternative land use. Results from a survey of 556 Canterbury-based rural decision-makers was used to identify the potential barriers and drivers that impact landowner's afforestation decisions. Combining the suitable land, economic analysis, drivers, and barriers of afforestation allowed inferences to be made about the Canterbury plantation forestry area's potential future size.

This study identified that there are over 1.2 million hectares of land deemed suitable for afforestation across the Canterbury region. Within the Hurunui TA, 82% of the suitable planting areas provided an economic return that exceeded the average return of the alternative land use (sheep and beef farming). None of the land identified as suitable for afforestation achieved the assumed forestry investment return requirement at the average land cost. However, if the land cost was reduced to the minimum of recent sales, 4% of the suitable land met the assumed required rate of return for forestry investment-based afforestation. The influence of land cost, log price and carbon price were observed to significantly impact the land deemed to be economically superior to the next best alternative land use, a sheep and beef farm.

Canterbury-based respondents of the 2019 Survey of Rural Decision makers identified that the main drivers for afforestation were predominately non-financial and prioritised decisions that accounted for the impact of afforestation at a farm level. These non-financial drivers lead to primarily non-commercial forestry species being identified for future planting. The primary barrier to afforestation

of opportunity cost further highlighted the consideration of the broader farming system. The financial cost of undertaking tree planting was also a significant barrier to land use change. However, the One Billion Trees Programme results identified that this barrier was able to be overcome when sufficient funding was available.

Estimation of the potential future size of the Canterbury forestry area was based on the expansion of the results of the Hurunui TA study to the wider Canterbury region and combined with the drivers and barriers of afforestation. If the land can be acquired at a minimum land cost, then 50,945 hectares meet the required rate of return for forestry investment-based afforestation. A total of 1.04 million hectares exceeds the return of the next best alternative land use. However, given the barriers and drivers for afforestation, a maximum of 14% of this area is likely to be planted in commercial forestry species. This suggests that the Canterbury plantation forestry area could increase by a maximum of 197,157 hectares—15% of the hill country land in the Canterbury region. At the current rates of afforestation, this expansion would occur over a period of 92 years.

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Table of Contents

ABSTRACT **2**
ACKNOWLEDGEMENTS **4**
Table of Contents **5**
List of tables **7**
List of figures **8**
CHAPTER 1: INTRODUCTION **10**
1.1. Problem Statement 10
1.2. Thesis Objectives 12
1.3. Thesis Outline 12
CHAPTER 2: LITERATURE REVIEW **13**
2.1. Determining Land Suitable for Afforestation 13
2.2. Methodologies to Identify Drivers and Barriers to Afforestation 16
CHAPTER 3: LAND SUITABLE FOR AFFORESTATION **19**
3.1. Introduction 19
3.2. Research Methodology 19
3.2.1. Identifying land suitable for afforestation 19
3.2.2. Hurunui case study 24
3.3. Results and Discussion 35
3.3.1. Land suitable for afforestation in Canterbury 35
3.3.2. Hurunui case study 44
3.4. Conclusions 67
CHAPTER 4: DRIVERS AND BARRIERS OF AFFORESTATION **70**
4.1. Introduction 70
4.2. Research Methodology 70
4.2.1. Survey of Rural Decision Makers 70
4.3. Results and Discussion 73
4.3.1. Survey of Rural Decision Makers 73
4.3.2. Agent drivers & barriers 75
4.3.3. Comparison of survey results to the results of past studies 88
4.3.4. Agent based modelling opportunity 94
4.4. Conclusions 97

CHAPTER 5: SUMMARY OF CONCLUSIONS **100**
5.1. Total area of land that could be planted as forestry in Canterbury 100
5.2. Proportion of land that is economically superior to the next best alternative land use 100
5.3. Drivers and barriers impacting afforestation........ 101
5.4. Potential future size of the Canterbury forestry area 102
5.5. Limitations and areas for further research........ 103
References **106**
Appendices **117**

List of tables

Table 1: LUCAS land use classes (MFE, 2012) 21

Table 2: Hurunui case study suitable planting areas predicted 300 Index vs Palmer et al. (2010) predicted 300 Index for Canterbury. 26

Table 3: Indicative New Zealand radiata pine log prices generic log types (MPI, 2019a)........ 27

Table 4: Forestry regime costs adjusted to 2020 $NZD using the PPI all industries outputs..... 33

Table 5: Forest land removed from LUC 5, 6 & 7 and the land suitable for afforestation (units = ha)........ 36

Table 6: Land suitable for afforestation by TA (units = ha) 38

Table 7: Percentage of existing exotic forest areas in each LUC Class 40

Table 8: Land suitable for afforestation including LUC 3 & 4........ 42

Table 9: Delivered Wood Cost summary for suitable planting areas ($ per tonne)........ 45

Table 10: Operating profit range of suitable planting areas in both $/m3 and $/ha........ 49

Table 11: Economic suitable land at varying IRR return requirements and land cost........ 56

Table 12: Suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return (Evison, 2018). 59

Table 13: Suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return at varying carbon prices 60

Table 14: Suitable planting areas with a higher IRR than a typical sheep and beef farm at varying carbon price and land cost 61

Table 15: Effect of a percentage change on the PFO 5 year LPI on the suitable planting areas with higher IRR than a typical sheep and beef farm total return 61

Table 16: Suitable planting areas with a higher IRR than a typical sheep and beef farm at varying PFO 5 year LPI and land cost........ 63

Table 17: Characteristics of study respondents (n = 556)........ 73

Table 18: Characteristics of study respondents primary farm (n = 556) 74

Table 19: Respondents top 5 most important past planting drivers (Full list in Appendix C - Table 5)........ 78

Table 20: Respondents most important future planting driver (Full list in Appendix C - Table 5) 81

Table 21: Sample, completion rates and response rates *(P. Brown et al., 2013)* 88

List of figures

Figure 1: Steps used to identify land suitable for afforestation 19
Figure 2: Example of individual "plantable areas" (left image including property titles)............... 25
Figure 3: Example of a VCM 2019 harvesting costs inputs (Visser, 2019) 25
Figure 4: TRV & 300 Index relationship for the Hurunui TA.. 27
Figure 5: Example of a VCM 2019 Roading Costs Input (Visser, 2019) 28
Figure 6: VCM 2019 Transportation Costs Inputs (Visser, 2019) 29
Figure 7: Distance to market road networks for Hurunui plantable areas................................... 30
Figure 8: Land suitable for afforestation 35
Figure 9: Land suitable for afforestation as a percentage of total TA 37
Figure 10: LUCAS of land suitable for afforestation... 38
Figure 11: Existing forest cover and land suitable for afforestation... 39
Figure 12: LUC class of existing exotic forest areas by TA 40
Figure 13: Land suitable for afforestation including LUC 3 & 4 41
Figure 14: LUCAS classification of LUC 3 & 4 land suitable for afforestation......................... 42
Figure 15: Suitable planting areas Hurunui case study 44
Figure 16: Delivered Wood Cost distribution by area 46
Figure 17: Average delivered wood cost composition (% of total DWC) 46
Figure 18: Input costs as a percentage of total DWC.. 47
Figure 19: Operating profit of suitable planting areas ($ per ha) 48
Figure 20: Suitable planting areas operating profit per m3 49
Figure 21: Operating profit distribution of suitable planting areas... 50
Figure 22: Sensitivity analysis of operating profit inputs 51
Figure 23: Internal rate of return distribution for suitable planting areas (no land cost) 52
Figure 24: Internal rate of return distribution for suitable planting areas ($5,575/ha land cost) 53
Figure 25: Internal rate of return distribution for suitable planting ($2,727/ha land cost) 54
Figure 26: Suitable planting areas with IRR's higher than 7% at a land cost of $2,727/ha 55
Figure 27: Suitable planting areas with IRR's higher than a typical sheep and beef farm at a land cost of $5,575/ha 57
Figure 28: Percentage of suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return 59
Figure 29: Effect of changing PFO LPI on the percentage of suitable planting areas with a higher IRR than a typical sheep and beef farm total return 62
Figure 30: Internal rate of return distribution for suitable planting areas including 1BT funding of $1,500/ha ($5,575/ha land cost)... 63

Figure 31: Marginal delivered cost curve for all suitable planting areas within the Hurunui TA 64
Figure 32: Marginal delivered cost curve for all suitable planting areas within the Hurunui TA with IRR's higher than a typical sheep and beef farm (Land cost = $5,575) 65
Figure 33: Past planting drivers 76
Figure 34: Past planting drivers - Commercial vs Lifestyle 77
Figure 35: Future planting drivers 78
Figure 36: Future planting drivers - Commercial vs Lifestyle 80
Figure 37: Average species percentage of the total land area of future planting 82
Figure 38: Average species percentage of the total land area of future planting - Commercial vs Lifestyle 83
Figure 39: Barriers to future planting 84
Figure 40: Difference in agent characteristics (expressed as a %) of future planting respondents compared to the average agent 86
Figure 41: Difference in primary farm characteristics of future planting respondents compared to the average agent 87

CHAPTER 1: INTRODUCTION

Canterbury's plantation forest area has been declining as land use priorities have favoured net-deforestation activities. This reduction in forest area is especially concerning to local domestic processors who have expressed concerns about long-term log supply.

This study investigates the likelihood of future afforestation and the opportunities for growing the plantation forestry area within the Canterbury wood supply region (Appendix A - Figure 1). The opportunities for afforestation have been recognised through identifying the land that is suitable for afforestation given the economic returns of forestry and alternative land use considerations. This identification has classified suitable land for afforestation as the areas that are not currently in forest cover, have a biophysical suitable for forestry, and, consequently, consider their economic suitability. Survey data has consequently been used to understand the impact that potential barriers and leverage points have on rural landowners' afforestation choices.

This study's results allow a conclusion to be made regarding the potential future size of the Canterbury radiata pine resource. Conclusions have been made by combining the land deemed economically suitable for planting alongside the portion of this land likely to be planted given the drivers and barriers of afforestation.

1.1. Problem Statement

Canterbury's plantation forest area has declined as landowners prioritise land use change to pastoral farming. The 2007 Canterbury Forest Industry and Wood Availability Forecast (WAF) reported approximately 5000 hectares having been converted to pastoral agriculture or for subdivision in the past three years. The 2007 WAF further reported another 9000 hectares across the region have been identified for conversion in the coming years. In the 2015 Canterbury Forest Industry and Wood Availability Forecast a decline of 27% of the modelled stocked area was reported when compared to the 2007 WAF (MAF, 2007; MPI, 2016b; Pangborn & Woodford, 2011). In addition to the deforestation through land use change, the Canterbury forestry industry has also been impacted by two significant wind events in 2013. It has been estimated that the resulting damage of these wind events is close to 1 million m3 of wood potentially flattened (Belton, 2013).

This reduction in the plantation forestry area will negatively impact log supply for the local domestic processors operating within the Canterbury wood supply region. Reduced log supply has the potential to lead to sawmill closures and consequent job losses within the region. Modelling provided in the 2015 WAF suggests the long term non-declining yield will reduce from the current levels of around 1.3 million m3 to just under 1 million m3 through to the early 2040s. At this point, supply progressively reduces to a low of 0.6 million m3 (Appendix A - Figure 2). This reduced supply has the potential to impact domestic supply through to 2040, at which point the available supply would decline to a level lower than the current domestic demand. The available supply for domestic processors is potentially reduced further if the volume of roundwood that exported through Lyttleton and Timaru Ports is maintained at the current levels (Table 2).

The future size of the Canterbury plantation forestry area is uncertain and without future afforestation is predicted to significantly decrease (MPI, 2016b). This study identifies the land suitable for forestry in the Canterbury region and explores the economic suitability of future afforestation. Furthermore, this study explores the potential barriers and drivers that may impact rural landowner's afforestation choices. With knowledge of the suitable land, the drivers needed for afforestation to occur and the barriers that need to be overcome a conclusion has been made regarding the maximum potential area of the Canterbury radiata pine resource.

Research Questions:

- What is the total area of land that could be planted as forestry in Canterbury?
- What proportion of this land is economically superior to the next best alternative land use?
- What potential barriers and leverage points may impact afforestation in Canterbury?
- Given the suitable land and potential barriers/drivers for afforestation, what is the potential future size of the Canterbury radiata pine resource?

1.2. Thesis Objectives

- Identify the total land area suitable for afforestation in Canterbury.
- Identify the land that is economically superior to the next best alternative land use.
- Identify the barriers and drivers that impact afforestation.
- Make a conclusion regarding the potential future size of the Canterbury radiata pine resource.

1.3. Thesis Outline

The thesis is presented as follows:

Chapter 2 provides a literature review of research documenting past studies of land suitable for afforestation, the drivers and barriers of afforestation and the methodologies used to explore these further.

Chapter 3 summarises the land suitable for afforestation within the Canterbury region and includes a case study economic analysis for the Hurunui TA. This chapter includes the methodology developed for identifying the land suitable for afforestation and the Hurunui case study analysis results.

Chapter 4 summarises the drivers and barriers of afforestation and compares the results of this study with comparative research. This chapter includes the methodology applied to analyse the survey data.

Chapter 5 summarises the main conclusions, the implications for the Canterbury plantation forestry area's future size and presents key areas for further research.

CHAPTER 2: LITERATURE REVIEW

This section considers relevant the literature and topics related to identifying land suitable for afforestation and the drivers and barriers of afforestation. Some results from previous applications of these approaches are summarised in the chapters that follow.

2.1. Determining Land Suitable for Afforestation

To investigate the potential for afforestation within the Canterbury region, this study first identifies the land with a biophysical suitability and which areas of this land have an economic suitability for production forestry. Economic suitability is of utmost importance as profitability has been identified as a significant factor impacting the establishment of new plantation forests in New Zealand. This is due to the primary management objective of plantation forests in New Zealand being to maximise financial returns (Le Heron & Roche, 1985; Nakajima, Shiraishi, Kanomata, & Matsumoto, 2017; Richardson, Skinner, & West, 1999).

The profitability of afforestation has previously been identified as being superior on sites of high productivity, as identified using productivity indices (Kimberley et al., 2005). An increase in productivity allows higher volumes to be produced at harvest and can typically achieve shorter rotation lengths. The effect of higher at harvest volumes or shorter rotation lengths is a net positive benefit for the returns achievable from forestry. (Fenton & Dick, 1971; Nakajima et al., 2017)

Consideration must be made to the other elements impacting the profitability of forestry such as stand level management. For the purposes of this study, a general management assumption is applied as described by Fenton and Dick (1971). Management practices have been assumed to maintain both economic and environmental sustainability in planted forests used for timber and carbon production (Nakajima et al., 2017). This suggestion of a single management assumption has been made as previous research has concluded that stand-level management variations have less impact on profitability than the underlying land productivity. Hunter and Gibson (1984) concluded that one of the most important variables influencing profitability was site productivity. Therefore, it is an important input to prioritise forest investment towards land that achieves a high productivity for forestry.

Two national measures of productivity of Radiata pine are applied within the New Zealand Forestry sector; Site Index and the 300 Index. Site Index provides a prediction of height growth while the 300 index is an index of mean annual volume increment (Palmer et al., 2010). Site index has historically been described as the universally accepted index for identifying site quality and, consequently, site productivity in New Zealand (Hunter & Gibson, 1984; Tesch, 1980). Site index specifically refers to the Mean Top Height at age 20 for *Pinus radiata*. It is observed to range from 15m to 40m throughout New Zealand, with higher MTH's generally observed in the North Island and lower in the South Island (Burkhart, 1977; Eyles, 1986; Zhao, 1999). Site Index is a useful measurement as it is relatively unaffected by differing management practices. However, site index is only weakly related to basal area growth, and therefore, only provides a partial measure of site productivity (Kimberley, West, Dean, & Knowles, 2005; Watt, Dash, Watt, & Bhandari, 2016). To improve industry knowledge of site quality and tree growth, Kimberley et al. (2005) developed a new measure of productivity named the 300 index. The 300 index is defined as the stem volume mean annual increment at age 30 for a Radiata Pine stand at 300 stems/ha stocking. However, the impacts of averaging plot values limit stand-level estimates of the 300 Index. This averaging approach does not consider site-specific attributes that can produce variation in site productivity such as climatic conditions, soil type, typography and altitude (Saremi, Kumar, Turner, Stone, & Melville, 2014; Véga & St-Onge, 2009; Watt et al., 2016).

David Palmer (SCION) has produced New Zealand-wide productivity maps predicting the Radiata 300 Index and Site Index for any chosen location. These productivity maps were built using data obtained from 1,146 permanent sample plots and combined with climatic, land use, terrain and environmental variables to predict productivity in varying locations with differing conditions (Palmer et al., 2010). The productivity maps produced by David Palmer provide a basis to identify the areas considered suitable for afforestation. These areas can be identified as highly productive and are likely to provide greater economic returns for forestry. (Fenton & Dick, 1971; Nakajima et al., 2017; Palmer et al., 2010; Richardson et al., 1999).

To correctly report the areas suitable for afforestation, consideration must be made for the high productivity area already under current forest cover. The 2016 National Exotic Forest Description (NEFD) reports the Canterbury wood supply region as having a total plantation resource of 96,860 ha. This area is estimated using data collected in NEFD questionnaires from forest owners and managers with at least 40 ha of planted forest alongside a Small Forest Grower Survey results for those owners with less than 40 ha (MPI, 2016a). The area reported in the NEFD is deemed somewhat inaccurate as the 2015 Wood Availability Forecast (WAF) for the Canterbury planted forest estate identified that it may have overestimated the area of plantation forestry in Canterbury. A 2014 mapping exercise by the University of Canterbury (UC) resulted in the forest estate being 45% less than reported in the 2014 NEFD. Considering the results of this mapping exercise, the 2015 WAF reported the net stocked forest area in Canterbury being 37,513 ha (MPI, 2016b).

To identify the site-specific land areas potentially suitable for afforestation a consideration of the different land classifications in the Canterbury region was made. On a general level, the New Zealand Land Cover Database (LCDB) provides a classification of New Zealand’s land cover. This database classifies land cover into 33 different categories by grouping similar land classes identified in satellite images (Dymond, Shepherd, Newsome, & Belliss, 2017; Newsome, Shepherd, & Pairman, 2013). More specific to this study are the 2012 Land Use and Carbon Analysis (LUCAS) maps. These maps have been produced to identify land use classes specific to the objectives of meeting climate change obligations. The identification of pre-1990 and post-1989 forest land areas and natural forest aligns with this study's objectives.

The LUCAS map's overall accuracy has been assessed to be 95.2%. All classes achieved accuracy above 90%, except for the grassland with woody biomass and wetland classes reporting accuracy of 59.9% and 85% respectively. Of fundamental interest to this study are limitations observed with some plantation forest areas being assessed as grassland with woody biomass due to the extent of tree heights or canopy cover (MFE, 2014). Additionally, it should be noted that the LUCAS map information is now eight years old, and it is likely that deforestation or afforestation on various land areas may have occurred. Given the discrepancies in areas reported by the NEFD and WAF, it is likely that a limitation exists regarding the actual area of plantation forestry in the Canterbury region.

2.2. Methodologies to Identify Drivers and Barriers to Afforestation

Land use and land cover change (LULCC) models are a well-developed approach to modelling and understanding the processes which shape the environment around us (L. Baker, 1989; Veldkamp & Lambin, 2001). LULCC models are capable of capturing a trend but are unable to explain or investigate the processes that caused the trend (Parker, Manson, Janssen, Hoffmann, & Deadman, 2003). Therefore, to investigate the processes that caused the trend, an alternative method must be used. Identifying the impact of drivers and barriers on the underlying decision-making trends is central to identifying the likelihood of afforestation. Knowing what land is suitable for afforestation is only useful if that landowner is willing and able to establish areas of forestry on their land. Therefore, it is essential to understand the factors influencing the landowners' decision-making process towards afforestation on suitable land.

P. Brown et al. (2013) identified that the wide range of diverse literature related to farmer decision making provided complications when undertaking future research. These barriers were identified as conflicting views, varying conceptual frameworks, different modelling approaches and differing theoretical perspectives. Journeaux et al. (2017) identified a wide range of factors that influence land use change. The drivers and barriers all interact in different ways and usually never in the same combination. Given the rural land use focus of this study, it has been deemed appropriate to apply a methodology that focuses specifically on the aspects of decision-making processes that are shaped by the drivers and barriers of afforestation in the Canterbury region.

Undertaking land use change is likely to be an infrequent, strategic decision rather than a frequent, tactical decision. It is more likely to include the influence of the agent's drivers and barriers during the decision-making process. An agent analysis can be used to explore land use change by incorporating the knowledge of the drivers and barriers impacting the decision-making process as, opposed to a purely economic analysis assumption (Daigneault & Morgan, 2014).

Previous studies have identified the need for a bottom-up process to capture how landowners vary in their land use preferences within an agricultural region. These studies identified that the chosen approach must consider the influence that personal, social and situation characteristics have on rural land use change decisions. To correctly interpret the behaviours of individuals, detailed information must be recorded and used in an analysis. Surveys and GIS and remotely sensed spatial data report quantitative information; while alternative options can produce qualitative interpretations. (Derek T Robinson et al., 2007; Rounsevell, Robinson, & Murray-Rust, 2012; Smajgl, Brown, Valbuena, & Huigen, 2011). However, there is no single perfect methodology that can be applied to investigate all aspects of a land use change. These factors, combined with the study's larger geographical area, give preference to using sample survey data within this study (Balmann, 1997; Berger, 2001; Derek T Robinson et al., 2007).

Robinson, Robinson, Brown, Parker, and Schreinemachers (2007) recognised five different main approaches that can be used to collect data. Given the study's large geographical area, it was identified that a survey data was the best option for data collection within this study (Balmann, 1997; Berger, 2001; Derek T Robinson et al., 2007). The use of surveys is common within previous agriculture research and for constructing land use models (P. Brown et al., 2013; Feder, Just, & Zilberman, 1985; Greiner, Patterson, & Miller, 2009; Kington & Pannell, 2003; Matthews, Gilbert, Roach, Polhill, & Gotts, 2007; O'Rourke, Kramm, & Chisholm, 2012; Vanslembrouck, Van Huylenbroeck, & Verbeke, 2002).

Surveys can be undertaken in person, over the telephone or using an internet-based approach. Both in-person and telephone surveys yield a higher response than internet surveys. However, the costs incurred when collecting data are significantly higher as they require trained enumerators to stimulate meaningful results (Balter, Balter, Fondell, & Lagerros, 2005; D. Brown, Walker, Manson, & Seto, 2004; Couper, 2011; Manfreda, Katja Lozar, Michael, Jernej, & Iris, 2008; Shih & Fan, 2008). A web-based survey was determined to be the most appropriate data collection method. The main advantage of using a web-based survey method is to broadcast the survey to a large sample pool and increase the chances of a successful response rate. Journeaux et al. (2017) identified a wide range of factors that influence general land use.

Based on the budget and scope of this study, web-based survey data was identified as the most appropriate data collection method for undertaking the consequent analysis. The collection of data from a sufficient number of respondents will enable an analysis of the factors related explicitly to afforestation.

The Landcare Research Survey of Rural Decision Makers (SRDM) 2019 uses the above strategies to overcome the challenges of a large geographical area being studied. The SRDM applies a web-based survey methodology when attaining their responses. Respondents are invited by e-mail to take part and are incentivised to complete the survey through the opportunity to select a charity to receive a donation. The Survey of Rural Decision Makers is completed by farmers, foresters, and growers and attracts some 3,740 respondents representing all primary production types from across New Zealand (Stahlmann-Brown, 2019). The use of the SRDM data within this study provides an opportunity to identify the drivers and barriers of afforestation and explore the impact on these may have on future afforestation.

CHAPTER 3: LAND SUITABLE FOR AFFORESTATION

3.1. Introduction

The land suitable for afforestation within the Canterbury region has been identified to provide a quantitative insight into the area currently available for plantation forestry. Furthermore, a Hurunui TA case study has been used to explore the economic suitability of the land identified as suitable for afforestation.

3.2. Research Methodology

3.2.1. Identifying land suitable for afforestation

The land suitable for afforestation was identified using the steps outlined in Figure 1 below. Further details on the methodologies applied are provided under the sub-headings below.

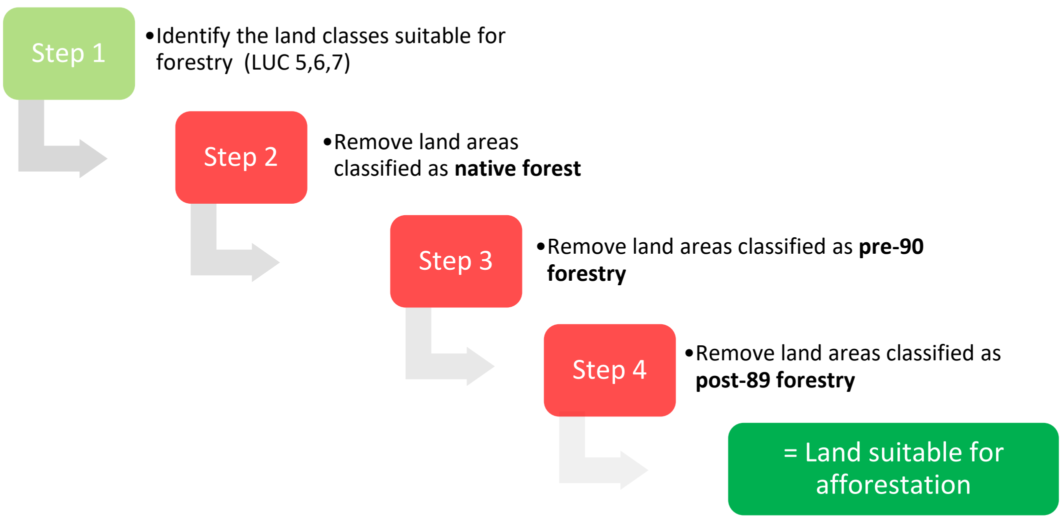


Figure 1: Steps used to identify land suitable for afforestation

Step 1: LUC forestry classification

To identify the land suitable for afforestation the New Zealand Land Resource Inventory (NZLRI) Land Use Capability (LUC) classification description was used to produce a map of the Canterbury region separated by LUC classes. The LUC classification a systematic arrangement of different kinds of land according to the properties that determine its capacity for long-term sustained production. The LUC

Class provides an assessment of the land's capability for use, taking into account any physical limitations and its suitability for sustained production (New Zealand et al., 1969).

The NZLRI LUC dataset was accessed using the Land Resource Information Systems Portal (Landcare Research, 2010) and was downloaded as a shapefile for GIS analysis. The database was imported into ArcGIS; a geographic information system used for mapping and analysing geographic information. For this and all subsequent GIS analysis tasks, the NZGD2000 New Zealand Transverse Mercator map projection was selected and applied within ArcGIS when processing this data.

The NZLRI LUC database was cropped to the Canterbury region and reduced to LUC Classes 5, 6 & 7 due to this land being deemed to have a general suitability for production forestry use (Lynn et al., 2009). This was undertaken using a "select by attributes" query and exporting a new dataset of LUC567 land. This dataset was further cropped into Hurunui, Selwyn, Waimakariri, Christchurch, Ashburton, Timaru, Mackenzie and Waimate territorial authority (TA) boundaries. This crop enabled a summary of suitable land for production for each TA to be provided. Finally, the 'Add Geometry Attributes' geoprocessing tool was used to add the geodesic area geometry property to each polygon within the new LUC567 datasets. The geodesic area algorithm was chosen as it was identified to be a highly accurate way to calculate area measurements of geographic features. "The area attributes obtained via the geodesic functions are superior to those of the Euclidian functions, as the Euclidian functions are based upon a projection (i.e. a flat 2D representation of a 3D surface) which introduces distortion" (ArcGIS, 2015). Summaries of the total area of LUC 5, 6 and 7 classes and land within each TA were generated using Microsoft Excel's SUMIF formula using the LUC Class as the sum criteria.

Step 2, 3 & 4: Remove land areas currently in “forest”

To identify the land ‘suitable’ for afforestation, the areas of current forest located within the LUC Class 5, 6 & 7 land were removed. The Land Use and Carbon Analysis System (LUCAS) NZ Land Use Map data was used to identify the current areas of forest (MFE, 2019). Produced for the New Zealand Ministry for the Environment, the LUCAS maps identify eight land use classes outlined in Table 1 below. LUCAS is used for accounting and reporting on afforestation, reforestation and deforestation activities to ensure New Zealand meets its international reporting requirements under the Kyoto Protocol (MFE, 2012).

Table 1: LUCAS land use classes (MFE, 2012)

2012 Land Use Classes	LUC_ID	Merged Classes
Natural forest	71	Natural forest
Pre-1990 planted forest	72	Pre-1990 planted forest
Post-1989 forest	73	Post-1989 forest
Grassland - with woody biomass	74	Grassland - with woody biomass
Grassland - high producing	75	Grassland
Grassland - low producing	76	
Cropland - perennial vineyards	77	Cropland
Cropland - annual	78	
Wetland - Open water	79	Wetland
Wetland - Vegetated non forest	80	
Settlements or built-up area	81	Other
Other	82	

The LUCAS dataset was accessed using the Ministry for the Environment (MFE) Data Service, downloaded as a shapefile and imported into ArcGIS for analysis. Using the 2016 classifications, the LUCAS database was split into three separate datasets: LUC ID 71 Natural forest, LUC ID 72 Pre-1990 planted forest, and LUC ID 73 Post-1989 planted forest (Table 1). The complete descriptions for these classifications can be found in Appendix B - Table 1. This geoprocessing task was undertaken using a “select by attributes” query and exporting a new dataset for each category. The new datasets were cropped into Hurunui, Selwyn, Waimakariri, Christchurch, Ashburton, Timaru, Mackenzie and Waimate territorial TAs. Cropping this dataset by TA was undertaken to align with the LUC datasets for classes 5, 6 and 7 datasets and to enable further geoprocessing tasks of this large dataset. The geodesic area geometry property for each polygon was calculated for each of the

Natural forest, Pre-1990 planted forest and Post-1989 planted forest datasets, and summary statistics were produced using Excel.

The areas of current forest cover were removed using the “Modify Features: Clip” geoprocessing tool to identify the LUC database areas that intersect with the layers representing forest cover. Three separate Clip tasks were undertaken for each TA to identify and remove natural forest areas, Pre-1990 planted forest and Post-1989 planted forest. After completing each Clip task, a new dataset was created to report the area removed during each clip. This was undertaken to allow a summary to be generated of the total area of Natural forest, Pre-1990 planted forest and Post-1989 planted forest contained within the LUC 5, 6 & 7 land classes in each TA. With the land in current forest cover removed, the LUC567 dataset's remaining area produced the land suitable for afforestation.

Analysis: LUCAS definition of the land suitable for afforestation

An analysis was undertaken to analyse the LUCAS definitions of the land deemed suitable for afforestation. The LUCAS definitions were identified using the geoprocessing “Modify Features: Clip” geoprocessing tool to clip the LUCAS data map to the land suitable for afforestation area. Geodesic area geometry properties for each LUCAS dataset polygon were calculated (by TA), and summaries of the LUCAS definitions were generated using Microsoft Excel’s SUMIF formula using the LUCAS definitions as the sum criteria.

Analysis: Current LUC classes of planted forest

An analysis was undertaken to explore the LUC class of the current plantation forest areas. This analysis utilised the datasets for the pre-1990 planted forest, and post-1989 planted forest to identify the underlying LUC class they were contained within. This was undertaken using the Clip geoprocessing function to extract the input features; being the LUC class overlapped by the clip features. The pre-1990 planted forest and post-1989 planted forest shapefiles were processed individually to extract a separate LUC class dataset for each forest classification. Again, the resulting datasets were cropped by TA, the geodesic area geometry attributes added, and summaries generated using Microsoft Excel's SUMIF to allow a comparison to the previous datasets.

Analysis: LUC 3 & 4 land suitable for afforestation

A significant percentage of existing forestry was identified to be contained within LUC Classes 3 & 4. An analysis was undertaken to explore additional land suitable for afforestation within the LUC 3 & 4 classes. This was undertaken using the NZLRI LUC database and reducing the dataset to the LUC Class 3 & 4 land. This task was undertaken using a "select by attributes" query and exporting a new LUC3 & 4 land dataset. Again, this dataset was further cropped into Hurunui, Selwyn, Waimakariri, Christchurch, Ashburton, Timaru, Mackenzie and Waimate territorial authorities (TA) and the geodesic area geometry for each property was using the LUC classes 3 & 4 dataset.

As per steps 2, 3 & 4 in Figure 1, the land 'suitable' for afforestation required the removal of areas of current forest located within the LUC Class 3 & 4 land. Consistent with the previous method the areas of current forest coverer were removed using the "Modify Features: Clip" geoprocessing tool to identify the areas of the LUC34 database that intersect with the Natural forest, Pre-1990 planted forest and Post-1989 planted forest layers. The geodesic area for each polygon was calculated for the remaining non-forest cover area of the LUC34 dataset to produce a summary of the additional LUC 3 & 4 land suitable for afforestation.

3.2.2. Hurunui case study

A further analysis of the land suitable for afforestation was undertaken within the Hurunui TA to explore the economic suitability of these areas. Economic suitability was identified as the suitable areas that are economically superior to the next best alternative land use.

Land suitable for afforestation in Hurunui

The land suitable for afforestation within the Hurunui TA was identified in the previous mapping exercise steps. The LUC 3 & 4 land identified as potential additional land suitable for afforestation has been excluded from the Hurunui case study as being outside of the range deemed as having a general suitability for production forestry use (Lynn et al., 2009). The land deemed suitable for afforestation was consequently dissected into privately owned land parcels using ArcGIS to create individual "suitable planting areas". The private property boundaries were identified using LINZ property title areas. This dissection was undertaken using the LINZ Data Service 'NZ Property Titles' database cropped to the Hurunui TA. Suitable planting areas less than 1 ha in size were removed for consistency with the classification of "Forest land" post-planting. Under the ETS, forest land must be at least a hectare in size and have tree crown cover of more than 30%, an average width of at least 30m and be a species capable of reaching at least 5m in height when mature (MPI, 2020a). Crown-owned land was not included within the suitable planting areas to limit this analysis to private land ownership. The output of these cadastral-defined areas was used to identify the individual "suitable planting areas" within the Hurunui case study analysis (Figure 3 below).

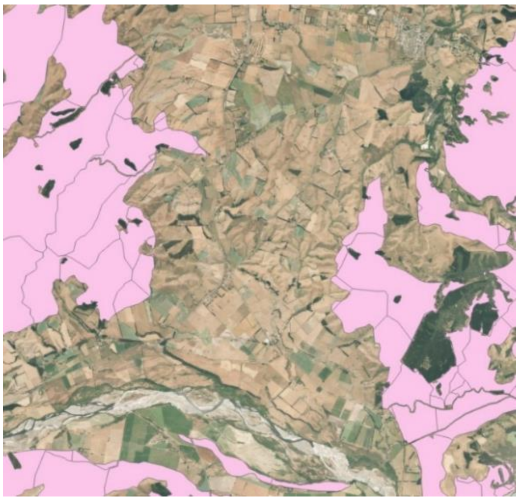


Figure 2: Example of individual "plantable areas" (left image including property titles)

Delivered Wood Cost

The Visser Costing Model 2019 (Visser, 2019) was used to calculate the delivered wood cost (DWC) for each potential planting area. The VCM 2019 is a Harvesting, Roading and Log Transportation Costing Model produced by Rien Visser at School of Forestry, University of Canterbury. The delivered wood cost was calculated using the VCM 2019 components of "Harvesting costs" + "Transportation costs" being Harvesting Cost + Roading Cost + Distance to Markets as calculated as per the methodology outlined below.

Harvesting cost

Harvesting Costs			
50	Total contiguous forest area (ha)		
560	Expected volume per hectare (t/ha)		
40	Average slope of terrain in %		
11	# Log Sorts	$36.5	per tonne

Figure 3: Example of a VCM 2019 harvesting costs inputs (Visser, 2019)

TOTAL CONTIGUOUS FOREST AREA

The input for "Total contiguous forest area" was produced using the "suitable plantable areas" previously defined. These "suitable plantable areas" are defined by the land deemed suitable for afforestation within the mapping exercise (>1 ha) and segmented into individual land parcels as defined by LINZ legal boundaries.

Expected volume per hectare

To calculate the expected at harvest volume per hectare, a combination of the 300 index and the New Zealand Forest Research Institute Forecaster Calculator was utilised.

The 300 Index is an index of the mean annual increment (m3/ha/year) for radiata pine across New Zealand (Palmer et al., 2010). The dataset was provided by Scion as a raster and imported into ArcGIS for analysis. For each suitable plantable area in the Hurunui TA, the mean 300 index value was calculated using the slope raster and the Zonal Statistics as Table (Spatial Analyst) tool and assigned as an attribute. Additionally, suitable planting areas assigned with a 300 index value of 0 were removed due to limitations in the data. A summary of the 300 index values assigned to each of the suitable planting areas is shown in Table 2 below alongside a comparison of the predicted 300 Index for the Canterbury region (Palmer et al., 2010).

Table 2: Hurunui case study suitable planting areas predicted 300 Index vs Palmer et al. (2010) predicted 300 Index for Canterbury.

	300 Index mai (m3/ha)		
Region	Average	Range	
		Low	High
Hurunui case study plantable areas	24.5	9.8	32.8
Canterbury	22.2	8.2	38.7

Using the Forecaster Calculator, a relationship between the 300 index and the at harvest total recoverable volume (TRV) was generated. This was undertaken by varying the 300 index input and recording the forecaster calculators TRV output. During this calculation, the other site inputs remained static as only to observe the relationship between 300 index and TRV (Static model inputs can be found in Appendix B - Table 2). The resulting relationship between TRV and 300 Index is shown in Figure 4 below.

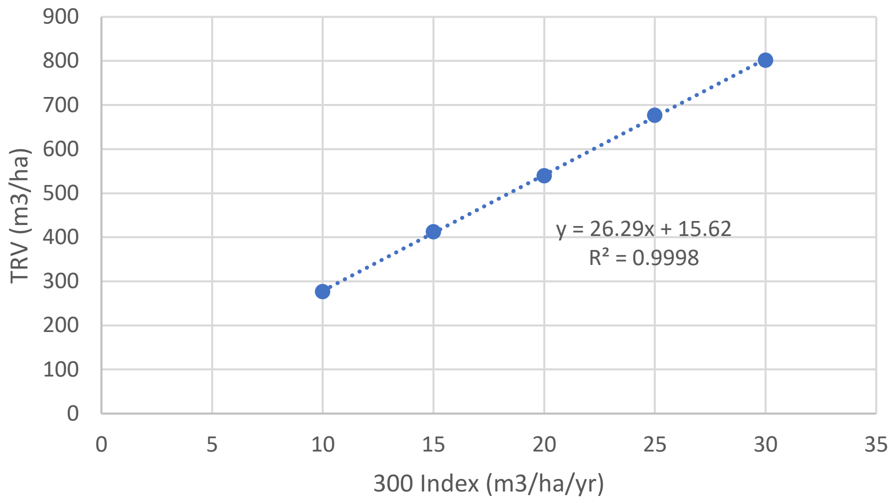


Figure 4: TRV & 300 Index relationship for the Hurunui TA

Average slope

To assign the average slope for each suitable planting area, a slope data layer was used from the Land Environments of New Zealand (LENZ) Digital Elevation Model (DEM) (MFE, 2020). A slope raster was created from this DEM using the Slope (Spatial Analyst) tool. The mean slope value for each suitable plantable area was calculated using the slope raster data and the Zonal Statistics as Table (Spatial Analyst) tool and assigned as an attribute.

Number of log sorts

The number of log sorts was assumed to be unchanged between blocks. The number of log grades was assumed to be 11 as per the Ministry of Primary Industry Indicative New Zealand radiata pine log price series shown in Table 2 below.

Table 3: Indicative New Zealand radiata pine log prices generic log types (MPI, 2019a)

Generic Log Type	
EXPORT	**DOMESTIC**
Pruned	P1
Unpruned A Grade	P2
Unpruned K Grade	S1
Pulp	S2
	L1 and L2
	S3 and L3
	Pulp

Roading Cost

The “Roading Cost” inputs in the VCM are shown below in Figure 5.

Roading Cost (access to harvest area)			
140	Meters of new road in hilly to steep terrain		
200	Meters of new road in flat to rolling terrain		
0	Meters of existing road needing improvement		
Yes	Fee for road maintenance (Yes, No)		
3	Number of landings (approximately 1 for every 6-8 ha.)	$3.8	per tonne

Figure 5: Example of a VCM 2019 Roading Costs Input (Visser, 2019)

Meters of new road

The roading requirements for the suitable planting area were provided by Dr Rien Visser from the College of Engineering (Forest Engineering) at the University of Canterbury. The average road length required per hectare was assumed as being 22 metres. The area of new road was categorised as “new road in hilly to steep terrain” for suitable planting areas with an average slope greater than 30% and as “new road in flat to rolling terrain” in suitable planting areas with an average slope less than 30%.

Existing Road

The assumption was made that there were no existing roads within the suitable planting areas and all roading is classified as “new road”.

Fee for road maintenance

The assumption was made for all suitable planting areas that there would be a fee for road maintenance to reflect the ongoing costs associated with using the road during harvest. Within the VCM the fee for road maintenance is set at a fixed rate of $2 per tonne at harvest.

Number of landings

The required number of landings is listed within the VCM 2019 as approximately 1 for every 6-8 ha. This range's lower value was used with an assumption of a landing every 6 hectares being required. For reasons of practicality, this was rounded to the nearest whole number.

Distance to markets.

The “Transportation Costs” inputs in the VCM are shown below in Figure 6.

Transportation Costs (forest to mill or port)			
0	Kilometers to be travelled on forest / unsealed road		
60	Kilometers to be travelled on sealed public road	$19.0	per tonne

Figure 6: VCM 2019 Transportation Costs Inputs (Visser, 2019)

Kilometres on forest / unsealed road

The number of kilometres to be travelled on forest / unsealed road was assumed to be the same as the “metres of new road” required for each suitable planting area in the roading costs calculation.

Kilometres on a sealed public road

To calculate the kilometres on a sealed public component of the distance to markets the "NZ Road Centrelines" layer from the Topo50 LINZ dataset was used. This layer represents the roads' actual physical formation and therefore, does not follow all legal road corridors. This methodology was used so that no unformed paper roads have been used in the calculation, only formed roads.

The market assumed was the log export port at Lyttleton. This assumption was made as domestic log prices are often adjusted to account for the cartage differential between their respective market and the log export port. It can be assumed that any impact to DWC due to variations in log market location would offset by this price adjustment. This assumption also avoids the problem of trying to account for processing facilities that have not yet been built or may not exist at the time of harvest.

Each road string within the layer above was assigned a weight (being the assumed speed) based on the "lane_count" and "surface" fields so that higher-order roads were given more weight in the final distance calculation. This helps prevent minor roads from being used as a shortcut by the algorithm. Additionally, the algorithm was forced to use the State Highway network south of the Waimakariri Bridge as per the New Zealand Transport Authority’s over-dimension vehicle route guidance (NZTA, 2007).

A centroid was calculated for each feature in the Land Parcels layer for use in the network distance calculation. The Shortest Path algorithm calculates a starting point for each land title that is the point on the Road layer closest to the centroid. The centroid may or may not represent the actual access point to the property. The use of the centroid approach within this calculation ensured the assumed entrance point for each property was optimised based on the shortest distance to the nearest road.

The "Shortest Path" algorithm was then run using the Road layer as the network and the Centroids layer as the start points. As previously noted, Lyttelton Port was used as the endpoint. This algorithm created the "Paths to Lyttelton Port" shapefile. A length field (in km) was then calculated for each path and assigned to each feature in the suitable planting areas Land Parcels shapefile. The path to Lyttelton Port for each shapefile is shown below in Figure 7.

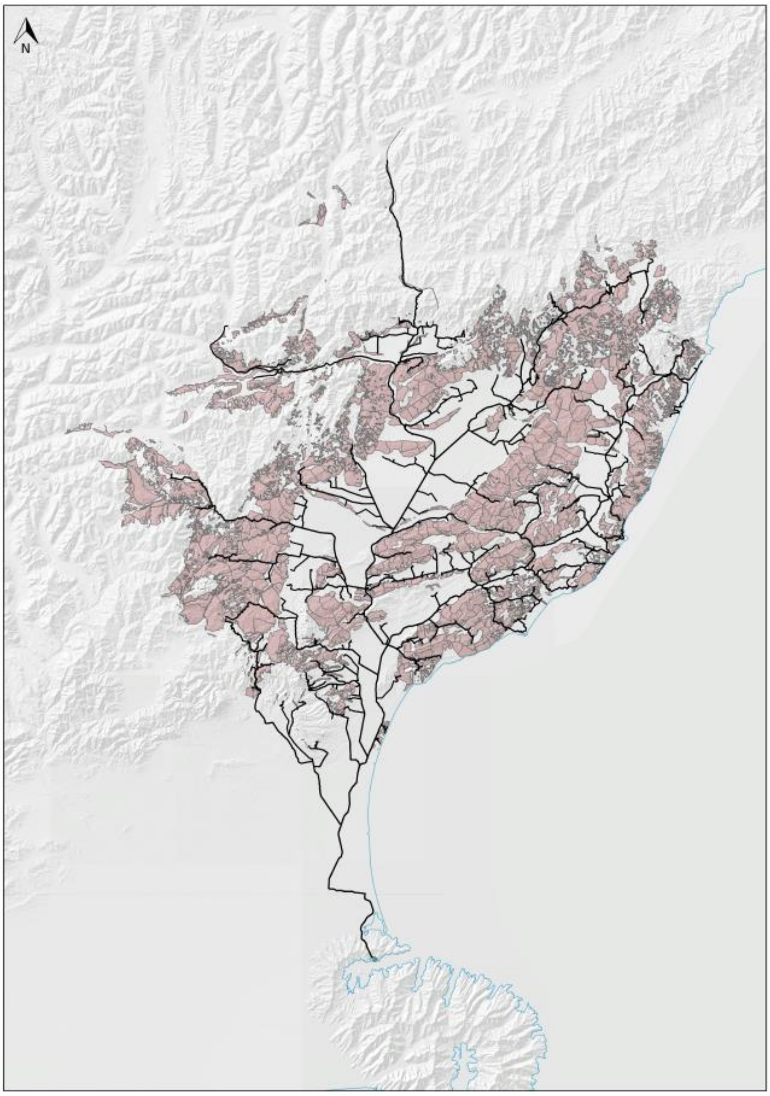


Figure 7: Distance to market road networks for Hurunui plantable areas

Operating Profit ($/ha)

The operating profit for each suitable planting area has been calculated to assign the return for each suitable plantable area. The operating profit represents the net return at harvest once the cost of production have been removed. To calculate the operating profit for each suitable planting area, the PF Olsen Log Price Index five-year average of NZD $120/sales unit (JASm3 or Tonne) was applied. The PF Olsen Log Price Index represents a weighted average log price for the log grades produced from a typical pruned forest with an approximate mix of 40% domestic and 60% export supply (PF Olsen, 2020). The use of this log price index was chosen for consistency with the Forecaster Calculator’s silvicultural regime input that simulated TRV from a Clearwood regime (Appendix B - Figure 1).

The operating profit for each suitable plantable area was first calculated as an operating profit per m3 and consequently converted to a per hectare operating profit value using the calculation below.

PFO Log Price Index five year average – DWC = Operating profit ($/m3)
- Operating profit ($/m3) * TRV (m3/ha) = Operating profit ($/ha)

Profitability ranking

Individual suitable plantable areas were ranked by the ‘at harvest profitability’ using the calculated operating profit ($/ha). The suitable plantable areas with the highest calculated operating profit per hectare were ranked as the most profitable. The areas with the lowest calculated operating profit per hectare were ranked as the least profitable.

Economic analysis

As a metric for economic comparison of land use the Internal Rate of Return (IRR) for each suitable plantable area was calculated. The IRR calculation used the calculated operating profit value, carbon revenue and associated costs assigned to each suitable plantable area for an investment period of 30 years.

Carbon revenue

Carbon revenues were included for each suitable plantable area's IRR using the Canterbury/West Coast carbon Look-up Tables for Forestry in the Emissions Trading Scheme (MPI, 2017) and a $35 carbon price. The MPI fixed costs associated with the ETS were applied being an initial registration cost of $562.22 and an annual cost of $102.22 for undertaking an emissions return for each ETS participant. The carbon revenue in the IRR calculations assumed the suitable plantable areas were registered under the averaging scheme for future harvest, as opposed to being registered as permanent carbon forestry participants. Under the averaging methodology, an 'average age' of 17 for *Pinus radiata* has been assumed (i.e. the long-term carbon stock is achieved at age 17). The averaging methodology can be defined as a carbon accounting method in which an ETS participant receives carbon credits equivalent to the long-term average level of carbon storage in the forest across multiple rotations.

Land Cost

IRRs were calculated both excluding and including the land cost. To calculate the IRR including land cost, a land cost was assigned to each suitable planting area derived from recent sales evidence of North Canterbury Sheep and Beef properties. The sales evidence was limited to the properties that met the Beef and Lamb classification of South Island hill country of a carrying capacity of between two and seven stock units per hectare. From March 2018 to April 2020, 10 properties representing 5723 ha of land sales met this classification. Over these properties, the net sale price per hectare was, on average, $5,575 (Appendix B - Table 3). The model assumes that the land asset is bought at the start of the investment period and sold at the end (at the same real price).

Forestry Regime Costs

Cost assumptions are based on the forestry regime costs reported by Evison (2008) and adjusted to Q4 2019 prices using the Producer Price Index (PPI) (Statistics New Zealand, 2020).

Table 4: Forestry regime costs adjusted to 2020 $NZD using the PPI all industries outputs

Age	Operation Cost	$/ha
1-30	Annual cost	$126
1	Land preparation and planting	$1,494
5	Pruning (1st lift)	$1,146
6	Pruning (2nd lift)	$1,019
7	Thinning	$523
8	Pruning (3rd lift)	$891
10	Thinning	$581

IRR comparison

Source: Evison (2008)

The IRR calculated for each suitable plantable area ($5,575/ha land cost) was consequently compared to the typical discount rate used in forestry and the returns available from the next best alternative land use. The PCE (2019) case study suggested sheep and beef farming as primary land type modelled for conversion to forestry. Therefore, a sheep and beef farm has been assumed to be the next best alternative land use within this study.

Sensitivity analysis

To explore the impact of varying inputs, a range of different sensitivity analysis tasks were undertaken. These included varying carbon price, log price and the interaction of these with a changing land cost.

The carbon price's impact on the suitable planting areas IRRs used ranged from not being an ETS participant up to $50 per NZU. Additionally, the point at which 100% of the land deemed suitable for afforestation produces a higher IRR than typical sheep and beef farm was identified.

The impact of a varying log price explored a range of -30% to +30% of the PFO LPI. A polynomial regression model was applied to identify the PFO LPI limits for 0% and 100% of the suitable planting areas IRRs being higher than typical sheep and beef farm.

Finally, the One Billion Tree Programme funding's financial impact was identified by comparing the average IRR, including and excluding the funding. The direct landowner grant for Pinus radiata was applied. This grant category receives a base funding rate of $1,500 per hectare and requires a six-year stand-down period from the Emissions Trading Scheme.

Marginal delivered cost curve analysis

A marginal cost analysis was undertaken to produce the marginal delivered cost profile for the volume harvested under different scenarios. A marginal delivered cost curve was produced for all suitable plantable areas within the Hurunui TA, and the suitable planting areas within the Hurunui TA with IRRs higher than a typical sheep and beef farm. The marginal delivered cost curve was produced by undertaking the following steps:

- Calculate the volume for each suitable planting area.
- Calculate the harvesting and transport cost (delivered cost) for each suitable planting area.
    - Bin all data, using $1/m3 bins.
- Rank suitable planting areas in increasing order of delivered cost.
- Calculate the cumulative volume (from lowest to highest delivered cost).
- Divide the cumulative volume in each bin by the rotation age (30 years). This provides an estimate of the annual harvest volume, assuming the total suitable area is planted up over 30 years.

The dataset produced using this methodology was consequently plotted on a scatter graph with the Y-axis being “Delivered Cost ($NZ/m3)” and the Y-axis being “M3 harvested per year”.

3.3. Results and Discussion

3.3.1. Land suitable for afforestation in Canterbury

The land suitable for afforestation is shown in Figure 8 below. Across all TAs over 1.2 million hectares of land is identified as being suitable for afforestation.

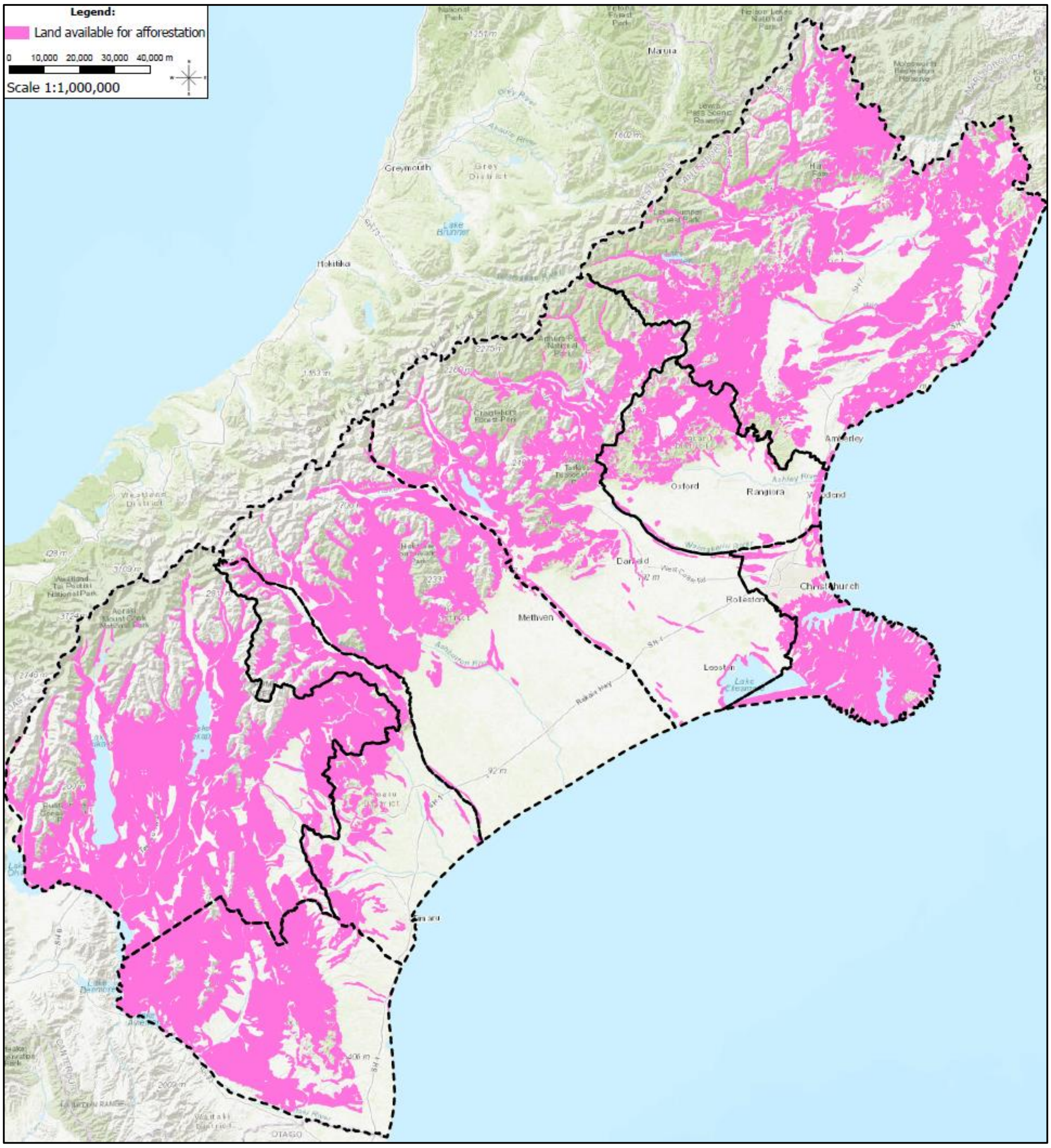


Figure 8: Land suitable for afforestation

To identify the land suitable for afforestation it was essential to explore the current land use for the areas defined by LUC classes 3 to 5 as having general suitability for production forestry use (Lynn et al., 2009). The removal of the areas currently in native and plantation forest cover was an essential step in reporting the land suitable for afforestation. The effect of the forest land removals from the LUC 5, 6 & 7 land is shown below in Table 5 alongside the resulting land suitable for afforestation.

Table 5: Forest land removed from LUC 5, 6 & 7 and the land suitable for afforestation (units = ha)

TA	LUC 5, 6 & 7	Native forest	Pre-90 exotic	Post-89 exotic	Land suitable for afforestation
Hurunui	416,882	-80,693	-19,811	-13,376	**303,003**
Selwyn	154,518	-30,348	-4,535	-4,282	**115,353**
Waimakariri	72,862	-34,200	-2,768	-1,403	**34,491**
Christchurch	95,838	-6,193	-4,222	-3,563	**81,860**
Ashburton	145,210	-6,588	-645	-446	**137,531**
Timaru	82,553	-4,202	-5,333	-5,549	**67,469**
Mackenzie	368,861	-3,559	-3,369	-7,352	**354,581**
Waimate	190,933	-4,756	-4,316	-2,521	**179,340**
Total	**1,527,657**	**170,539**	**-44,999**	**-38,493**	**1,273,626**

As observed in Table 5 above the most significant reduction in the area of LUC 5, 6 & 7 land deemed suitable for afforestation was due to land classified in LUCAS as native forest land. The New Zealand Forest Accord is an agreement between forestry interests and the environment and conservation organisations that made up the New Zealand Rainforest coalition. Under the New Zealand Forest Accord, it was agreed that land clearing to establish areas of plantation forestry land clearing would exclude areas of naturally occurring indigenous vegetation (Treeby, 1991). In total across all TAs, the exclusion of native areas accounted for an 11% reduction in the land suitable for afforestation. The reduction in the suitable land per TA was most significant in the Waimakariri TA with 47% of the LUC 5, 6 & 7 land removed due to native forest. The Selwyn and Hurunui TAs also had significant levels of reduction due to native forest with their LUC 5, 6 & 7 areas reduced 20% and 19% respectively.

Existing exotic forestry (both pre-90 and post-89) accounted for a total of 5.5% of the LUC 5, 6 & 7 area across all TAs. Timaru had h the highest proportion of LUC 5, 6 & 7 land containing exotic forestry (13% of suitable land). This was followed by Hurunui and Christchurch City TAs, both with an 8% reduction due to exotic forest cover. The Ashburton TA had minimal areas of exotic forest cover, with a reduction in the LUC 5, 6 & 7 land of less than 1%. These observations are consistent with the MPI (2019b) National Exotic Forest Description and the MPI (2016b) Wood Availability Forecast for Canterbury which both report similar trends for exotic forest cover on a TA level.

The land suitable for afforestation varied in total area and as a proportion of the total TA size (Figure 9).

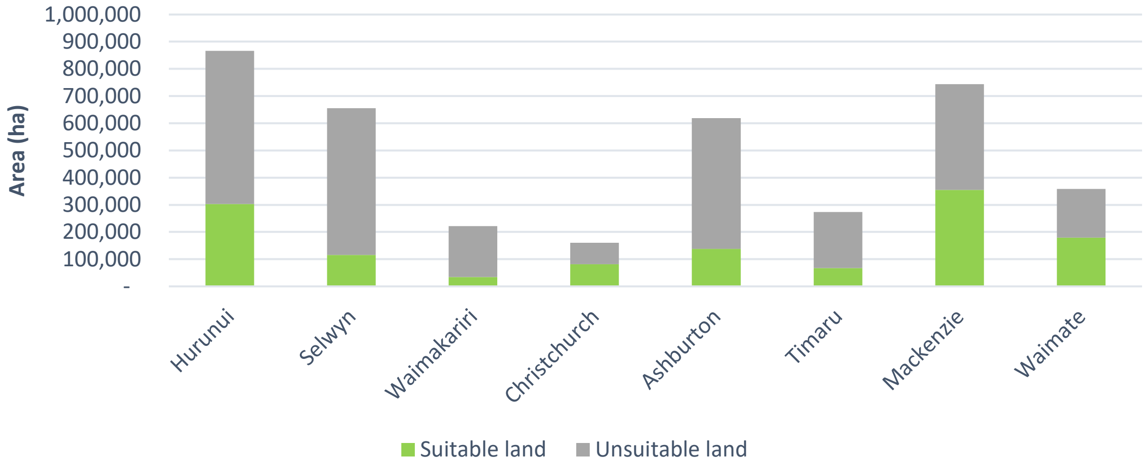


Figure 9: Land suitable for afforestation as a percentage of total TA

The TAs with the lowest percentage of their total land suitable for afforestation were identified as the Waimakariri and Selwyn regions with suitable land being 16% and 18% respectively. The Christchurch City and Waimate TAs are both observed to present significant opportunities for expanding the area of forestry; both having over 50% of their total land identified as being suitable for afforestation. However, the Hurunui and Mackenzie TAs both have the highest total potential for afforestation, with 52% of the total land suitable for afforestation contained within these two TAs.

The land suitable for afforestation shown in Figure 8 is outlined by LUC class in Table 6 below. The majority of the land suitable for afforestation is contained within the LUC 6 & 7 classes with only 1% of suitable land in the LUC 5 class. This trend was consistent across all TAs.

Table 6: Land suitable for afforestation by TA (units = ha)

TA	LUC 5	LUC 6	LUC 7	Total suitable
Hurunui	2,347	230,722	69,934	**303,003**
Selwyn	1,150	76,858	37,345	**115,353**
Waimakariri	719	23,772	10,000	**34,491**
Christchurch	308	72,392	9,160	**81,860**
Ashburton	2,645	64,854	70,032	**137,531**
Timaru	496	43,927	23,046	**67,469**
Mackenzie	6,704	218,683	129,194	**354,581**
Waimate	179	116,670	62,492	**179,340**
Total	**14,547**	**847,877**	**411,202**	**1,273,626**

The LUCAS land use map classifies most of the land identified as suitable for afforestation as low producing grassland (Figure 10). This classification is consistent with LUC Class 5, 6 & 7 being deemed as having general suitability for production forestry use (Lynn et al., 2009).

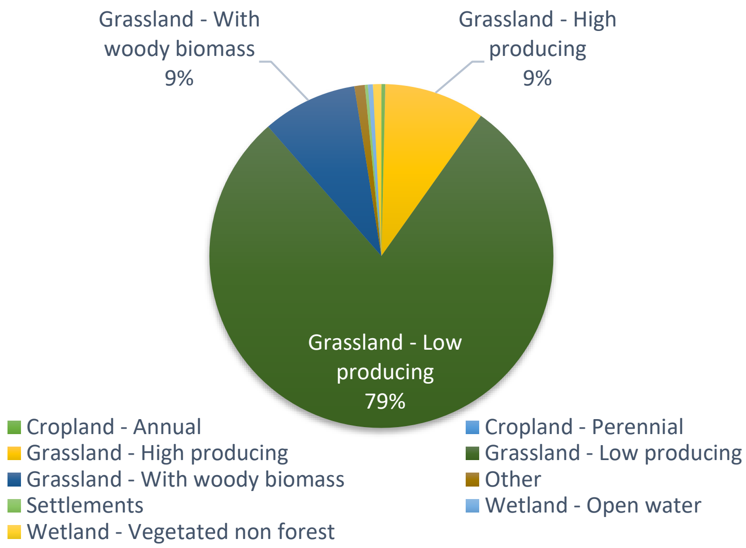


Figure 10: LUCAS of land suitable for afforestation

Contained within the land suitable for afforestation were small areas classified by the LUCAS system as Settlements (0.3%), Wetland – Open water (0.5%), Wetland – Vegetated non-forest (0.8%) and Other (1.0%) (Appendix B - Table 4 & 5). The LUCAS Land Use Map data description for these categories suggests that they are likely not to be suitable for afforestation (MFE, 2012). Therefore, it is suggested that there is a potential 2.6% of land identified for afforestation that may be unsuitable in reality.

LUC class of existing exotic forests

Figure 11 below displays the land suitable for afforestation alongside the existing areas of both native and exotic forest cover.

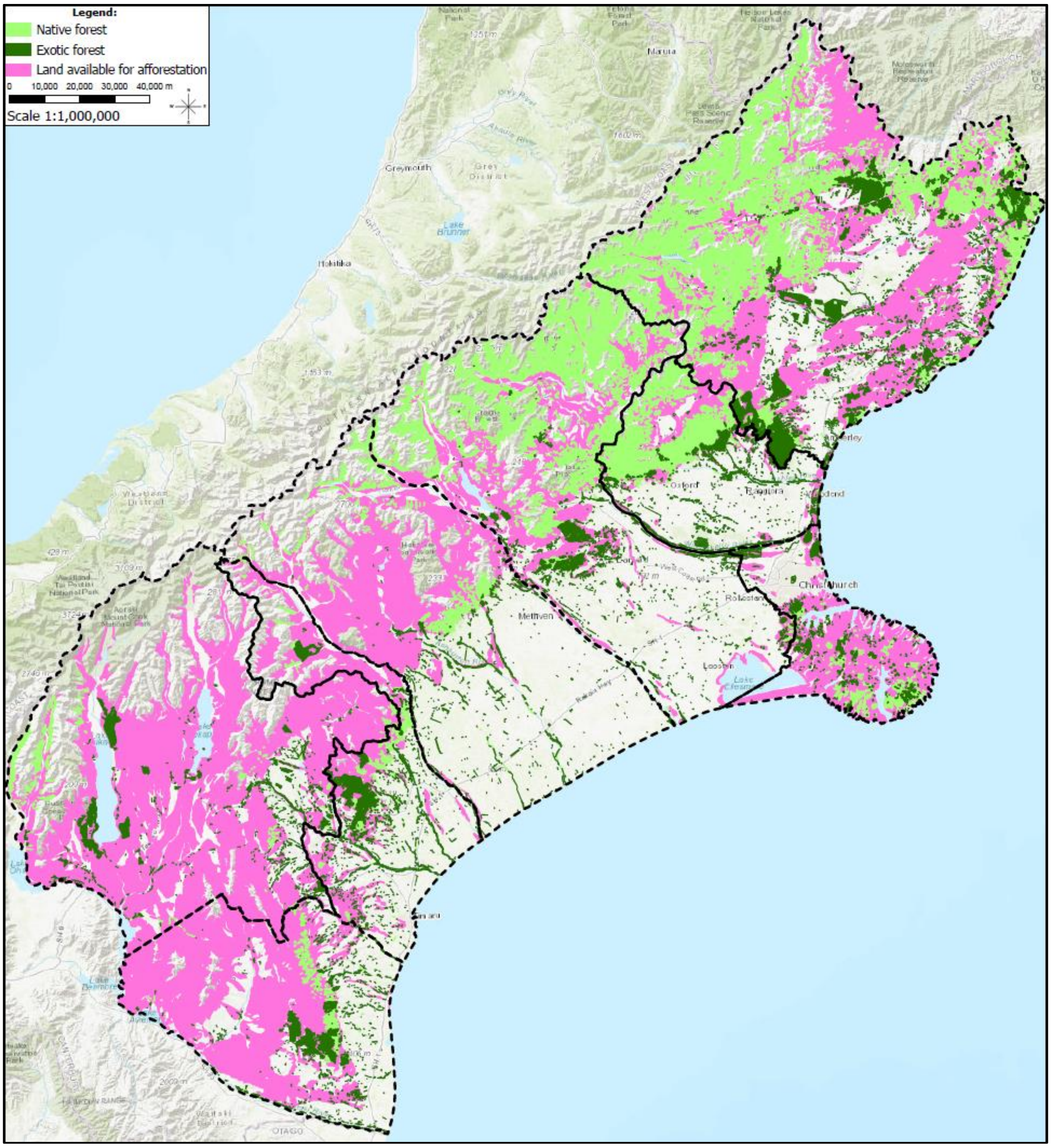


Figure 11: Existing forest cover and land suitable for afforestation

It was observed that a large portion of the existing exotic forest areas appeared to be located adjacent to the LUC 5, 6 & 7 classified land suitable for afforestation. However, it was also identified that there were areas of existing forest that were not immediately adjacent to these LUC areas.

Table 7: Percentage of existing exotic forest areas in each LUC Class

	LUC Class											
TA	1	2	3	4	5	6	7	8	e	l	r	t
Hurunui	0%	2%	**9%**	**16%**	*0%*	*59%*	*10%*	1%	0%	0%	3%	0%
Selwyn	0%	2%	**11%**	**20%**	*0%*	*51%*	*8%*	0%	0%	0%	6%	0%
Waimakariri	1%	5%	**17%**	**27%**	*0%*	*33%*	*6%*	2%	0%	0%	9%	0%
Christchurch	1%	1%	**2%**	**7%**	*0%*	*78%*	*7%*	0%	0%	0%	4%	1%
Ashburton	1%	6%	**29%**	**29%**	*0%*	*15%*	*2%*	0%	0%	0%	17%	0%
Timaru	0%	4%	**8%**	**10%**	*0%*	*66%*	*2%*	1%	0%	0%	11%	0%
Mackenzie	0%	0%	**6%**	**22%**	*1%*	*63%*	*6%*	0%	0%	0%	1%	0%
Waimate	0%	6%	**10%**	**21%**	*0%*	*50%*	*5%*	0%	0%	0%	8%	0%
Total	0%	3%	**10%**	**18%**	*0%*	*56%*	*7%*	1%	0%	0%	6%	0%

As shown in Table 7 above, 63% of the existing exotic forest areas were identified to be contained on LUC 5, 6 & 7 land. Of note is the percentage (28%) of existing forest areas contained on the higher quality LUC 3 & 4 land. The percentage of exotic forest area outside of LUC 5, 6 & 7 land was observed to vary between TAs (Figure 12).

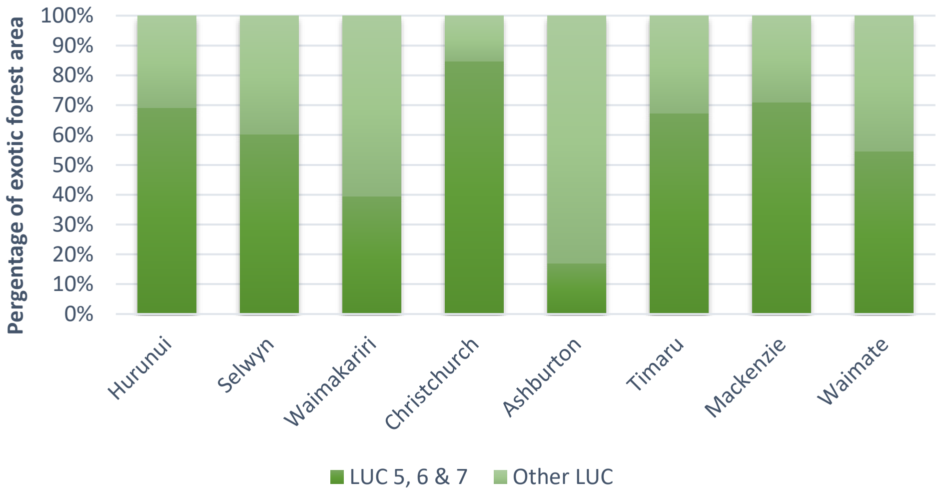


Figure 12: LUC class of existing exotic forest areas by TA

There is variation between TA's of the LUC class of existing exotic forests. The extremes of these variations are highlighted when comparing Christchurch City TA with 85% of the existing forest areas contained on LUC 5,6 & 7 land. At the opposite end of this range is the Ashburton TA with 83% of existing exotic forest areas on non-LUC 5,6 & 7 land.

LUC 3 & 4 land suitable for afforestation

Given the existing exotic forest areas contained on the LUC 3 & 4 land, an analysis was undertaken to identify the LUC 3 & 4 land deemed suitable for afforestation. The addition of the LUC 3 & 4 land is shown in Figure 13 below to significantly increase the total area of land identified as suitable for afforestation.

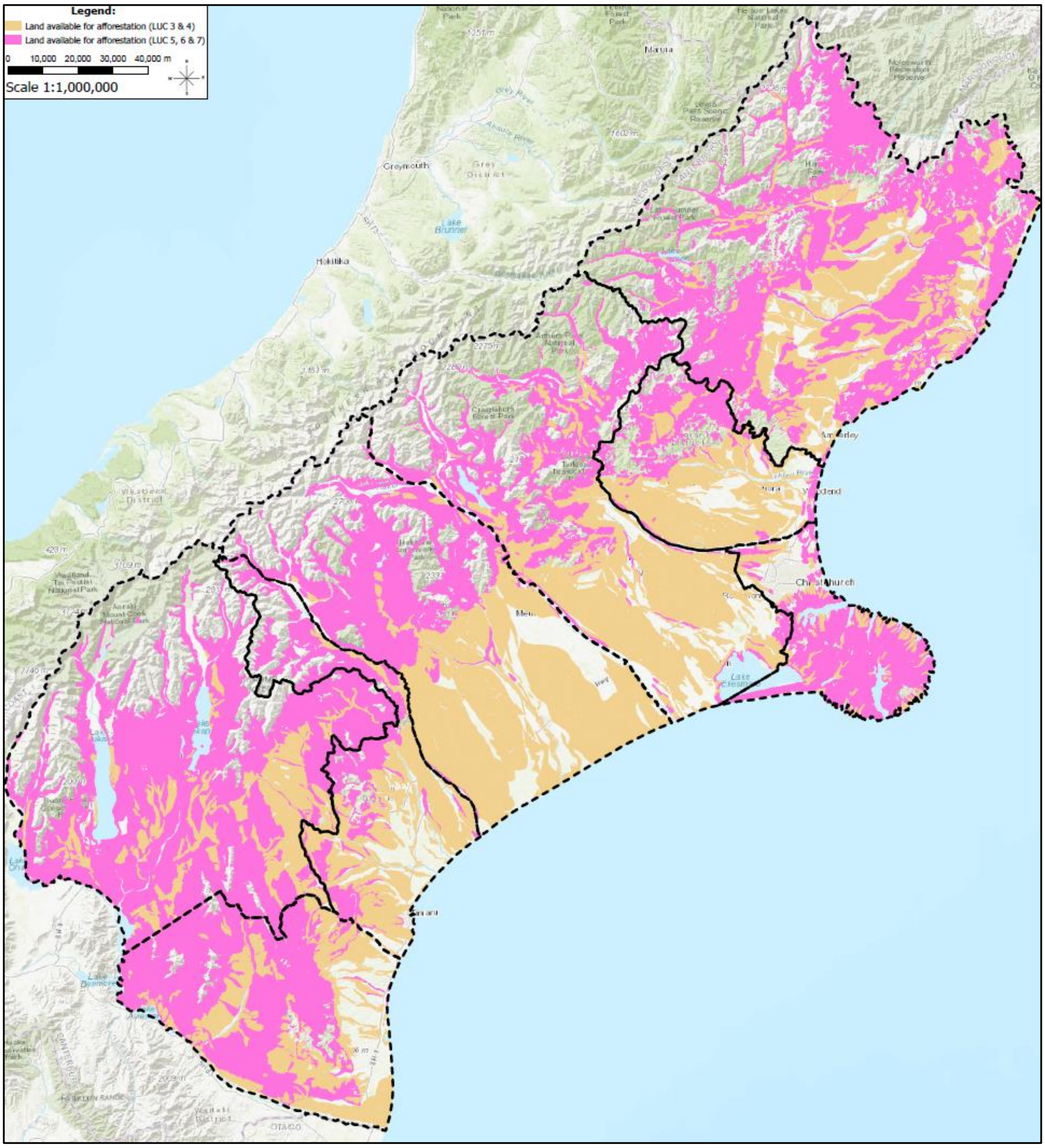


Figure 13: Land suitable for afforestation including LUC 3 & 4

With the inclusion of LUC 3 & 4, there are over 2.2 million hectares of land identified as suitable for afforestation across the Canterbury region (Table 8).

Table 8: Land suitable for afforestation including LUC 3 & 4

TA	LUC 3 & 4	LUC 5, 6 & 7	Total suitable
Hurunui	156,546	303,003	**459,549**
Selwyn	178,833	115,353	**294,185**
Waimakariri	90,331	34,491	**124,822**
Christchurch	18,817	81,860	**100,677**
Ashburton	237,170	137,531	**374,701**
Timaru	92,353	67,469	**159,821**
Mackenzie	91,824	354,581	**446,405**
Waimate	96,363	179,340	**275,703**
Total	**962,237**	**1,273,626**	**2,235,864**

The majority of LUC 3 & 4 land is classified as “Grassland – High producing” with areas also classified as “Cropland – Annual” (Figure 14). This is consistent with the LUC classification that identifies LUC 3 & 4 land as suitable for arable cropping or pastoral grazing (New Zealand et al., 1969).

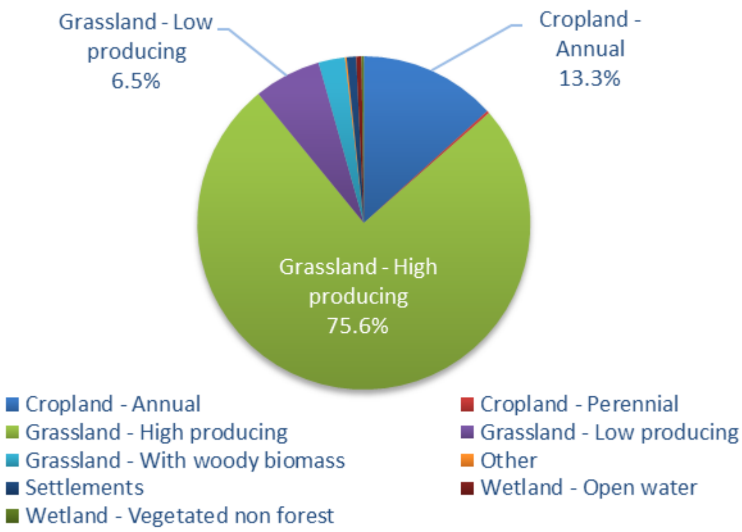


Figure 14: LUCAS classification of LUC 3 & 4 land suitable for afforestation

The addition of the LUC 3 & 4 land significantly increased the area of land identified as suitable for afforestation. However, it has previously been identified that current land use and the underlying land cost can have significant limitations to actual availability for afforestation. Land cost has a significant effect on the investment return to afforestation, and it has been identified that increased land values reduced the profitability of forestry on farmland (Evison, 2008). The additional LUC 3 & 4 areas contained a high percentage of the area classified by LUCAS as high producing grassland and annual cropland. Stillman (2005) reports a higher land value for this intensive pasture and arable land than the extensive pasture comprising the LUC 5, 6 & 7 land suitable for afforestation. Given the higher land costs reported for the predominant land types in the additional LUC 3 & 4 areas, it is likely that the LUC 3 & 4 land may not be suitable for afforestation as they would not be economically viable for forestry.

However, as previously reported, there has historically been land within the LUC 3 & 4 classes used to establish commercial forestry areas. If the historical trends from Table 7 above were explicitly used to indicate future land use, then a prediction could be made that 63% of new forest areas to be located on LUC 5, 6 & 7 land and 28% on the higher quality LUC 3 & 4 land. Additionally, using this methodology, it would also be expected that 10% of future forest areas would be located outside of the areas identified as suitable for afforestation on Figure 13 above (i.e. on classes 1,2 and 8).

3.3.2. Hurunui case study

The land suitable for afforestation within the Hurunui TA has been separated into individual suitable plantable areas, identified using the methodology described above. The results are displayed in Figure 15 below. In total, the Hurunui case study identified 246,454 hectares contained within 1,122 distinct suitable plantable areas.

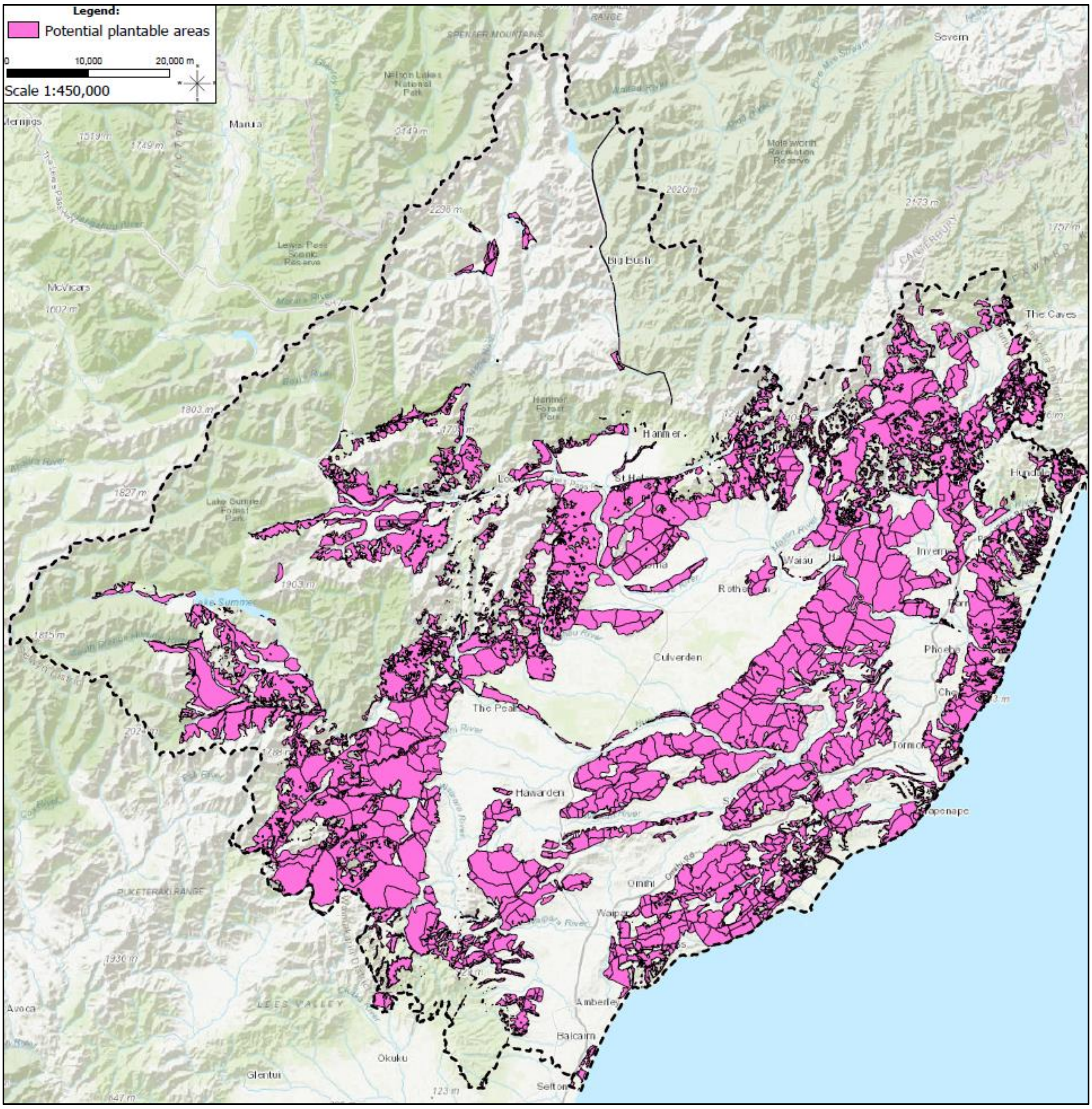


Figure 15: Suitable planting areas Hurunui case study

The suitable plantable areas within the Hurunui case study have an average area of 220 ha, slope of 20%, an assumed recoverable volume of 660 t/ha at a rotation age of 30 years and are located (on average) 120km from the market (Appendix B - Table 6).

The PCE (2019) Hurunui catchment case study was used as a comparison of the land identified as suitable for afforestation. The PCE study models land use within the Hurunui catchment assuming priority is based on targeting net-zero emissions. This report predicted that, under this assumption, 24% of the Hurunui catchment would be converted to plantation forestry by 2075. TAs. The PCE predicted area is less than the land identified as suitable for afforestation within the Hurunui TA above. Within the Hurunui TA, the total land suitable for afforestation was 35% of the total TA area. The PCE study's projected land use conversion to forestry of 24% of the Hurunui catchment is less than the 35% of the Hurunui TA identified as suitable for afforestation.

Delivered Wood Cost

The delivered wood cost (DWC) for each suitable plantable area represents the variable costs at harvest. The DWC excludes historic establishment, management and silvicultural costs. For each suitable plantable area, the DWC was calculated using the inputs summarised in Appendix 9. The average DWC for the suitable plantable areas was $73.33 per tonne. However, there was a significant variation within the range of DWCs from a minimum of $45.09 per tonne to a maximum of $117.88 per tonne (Table 9). The input with the largest cost range was transportation costs followed by harvesting costs.

Table 9: Delivered Wood Cost summary for suitable planting areas ($ per tonne)

	Min	Max	Mean
Harvesting Costs	$17.49	$64.86	$31.57
Roading Cost (access to harvest area)	$4.31	$13.94	$7.13
Transportation Costs (forest to mill or port)	$17.33	$83.26	$34.53
Delivered Wood Cost	**$45.09**	**$117.88**	**$73.22**

The distribution of delivered wood cost by area is shown below in Figure 16. This distribution follows an approximately normal distribution with 67% of the area within one standard deviation of the mean and 90% of the area within two standard deviations of the mean. There is an outlier area reported being 12,616 ha reported DWC's of over $115 per tonne.

Figure 16: Delivered Wood Cost distribution by area

On average, the transportation costs component was the largest portion of DWC, followed closely by harvesting cost (Figure 17). Roading cost only accounted for 10% of DWC, which was significantly lower than transportation and harvesting costs.

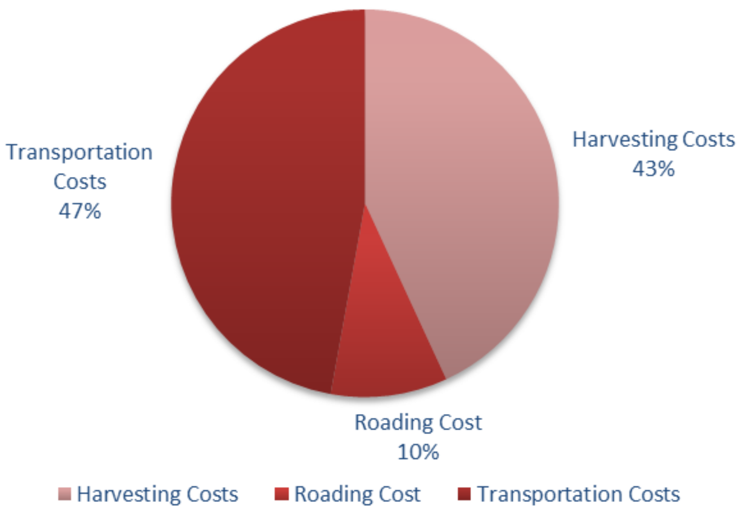


Figure 17: Average delivered wood cost composition (% of total DWC)

The transportation and harvesting cost inputs are observed to significantly impact DWC given their percentage contribution reported in Figure 17, and the extensive range reported in Table 9.

This impact is highlighted in Figure 18 below that reports the percentage contribution of each input cost to the total DWC. Consistent with Figure 17, roading cost is observed to be a significantly smaller component of DWC than harvesting and transportation costs. A clear trend is observed with the roading costs percentage of total DWC decreasing as DWC increases. There is no noteworthy overall trend observed in the percentage contribution of the harvesting and transportation costs as DWC increases. However, the previously reported ranges for input costs suggest that the transport costs can have the most substantial impact on DWC.

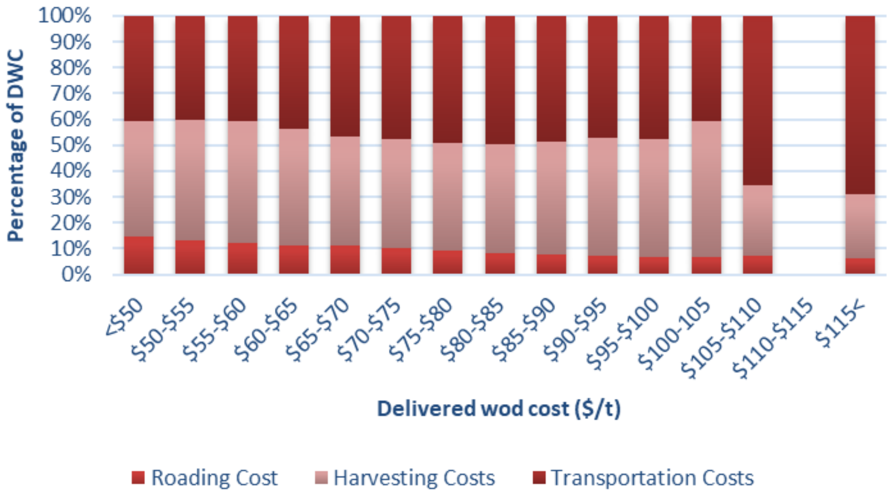


Figure 18: Input costs as a percentage of total DWC

At higher DWCs, the suitable plantable areas within the $100 - $105 DWC range can be described as having a steep average slope and high harvesting costs. For the outlier areas with a reported DWC of over $115 per tonne, the transportation costs are observed to be the primary component of DWC. Upon further investigation, these outliers are comprised of two large individual suitable planting areas of 5,474 and 7,142 hectares. The transport cost component was the driver for the high DWC for these areas being $79.2 per tonne and $83.3 per tonne respectively.

Profitability ranking

The operating profit represents the net return at the time of harvest. The operating profit was calculated both on a per m3 basis and a per hectare basis. The operating profit per hectare has been used as the basis for the profitability ranking in Figure 19 below, alongside the distribution of operating profit per m3 is shown in Figure 20 below.

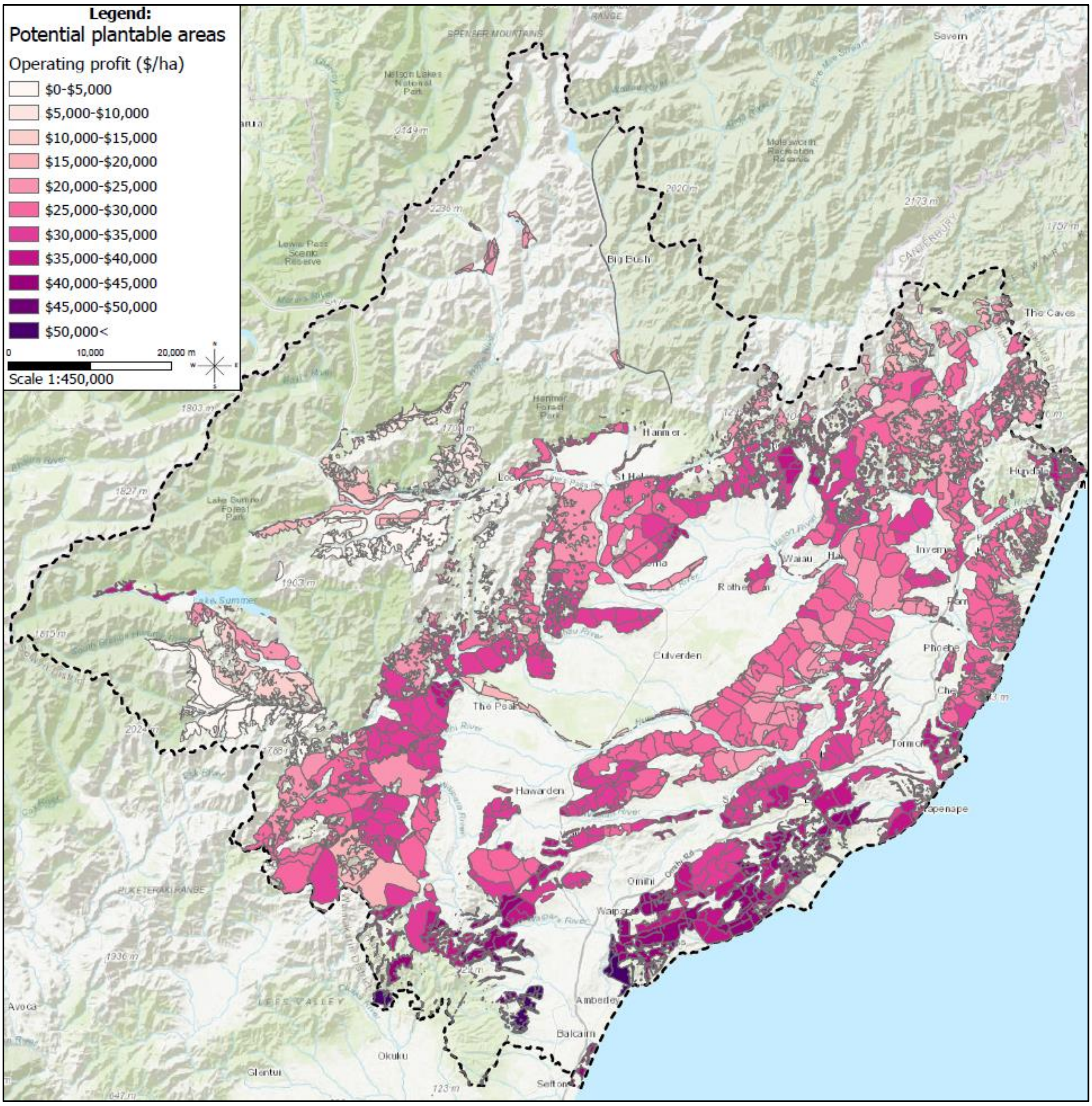


Figure 19: Operating profit of suitable planting areas ($ per ha)

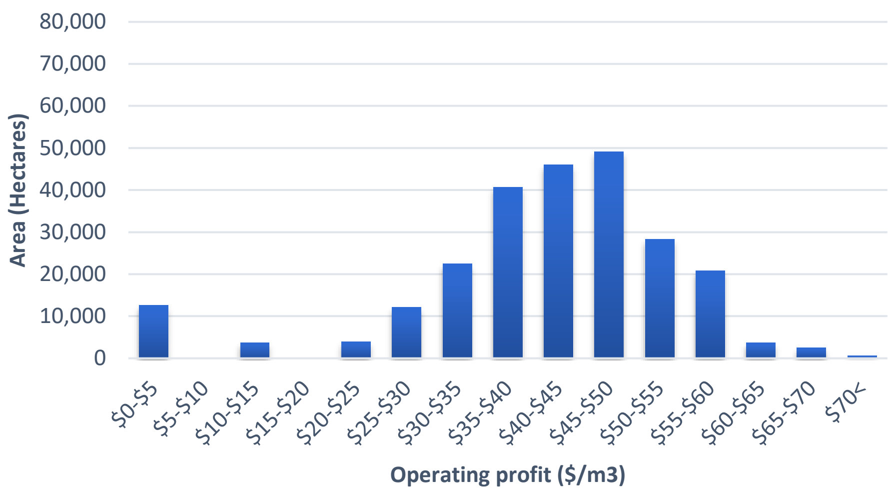


Figure 20: Suitable planting areas operating profit per m3

The suitable planting areas' operating profit was, on average, $30,738 per hectare and ranged from a minimum of $1,377 per hectare up to a maximum of $52,999 per hectare (Table 10).

Table 10: Operating profit range of suitable planting areas in both $/m3 and $/ha

	Min	Max	Mean
Operating profit ($/m3)	$2.12	$74.91	$46.78
Operating profit ($/ha)	$1,377	$52,999	$30,738

The operating profit reported in this study are consistent with the historic net returns ($/ha) reported by West (2019a). This report includes 12 datapoints of small-scale owner harvest returns from the Canterbury region with a net return per tonne ranging from $22 to $63 per m3 and $8,347 to $51,776 per hectare. Within this study, there are suitable planting areas that fall outside of the minimum net return reported by West (2019a). The less profitable suitable plantable areas identified are impacted by their underlying DWC. This effect is observed with the areas contained within the $0-$5,000 operating profit range being the same suitable planting areas reporting the high DWCs of over $115 per tonne (Figure 20 & Figure 16). The interaction between operating profit and DWC highlights that the profitability of forestry depends very much on location in respect to the market.

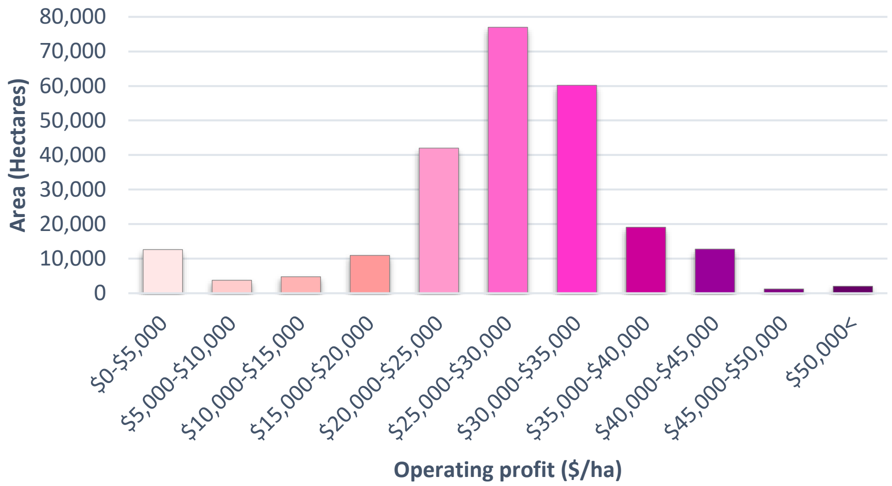


Figure 21: Operating profit distribution of suitable planting areas

The distribution of the net returns within this report's dataset is consistent on a per hectare basis with the distribution of the suitable planting areas operating profit shown in Figure 21. The survey data collected by West (2019b) is observed to have 81% of the Canterbury area net returns within the range of $20,000 to $35,000 per hectare. A similar trend is observed within this study, with 80% of the suitable planting areas operating profits in the range of $20,000 to $40,000 per hectare.

Sensitivity analysis

Figure 22 shows how the average operating profit per hectare changes as different input variables are increased or decreased. The gradient of the individual lines indicates which variable has the most significant impact on the rate of return; the steeper the line, the more impact it has on the operating profit. It is observed that a change in the PFO 5 year LPI has the most significant impact on the average operating profit per hectare. Harvesting costs and Transportation costs have the most significant impact on the cost side of the equation. However, their effect is less significant as the gradient of their lines are considerably less steep than the PFO 5 year LPI.

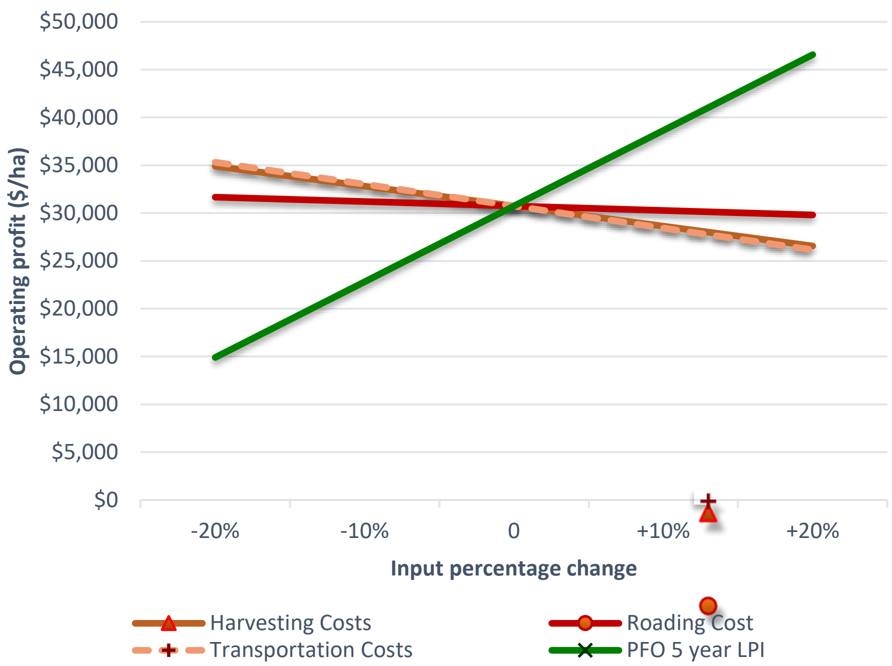


Figure 22: Sensitivity analysis of operating profit inputs

Economic analysis

Operating profit is more relevant to existing forests as this is immediately realised when a forest is harvested, or alternatively, is a driver for the forest not to be harvested. The likelihood of the suitable planting areas being afforested is addressed using an economic analysis that includes all revenues and costs throughout the life of a forestry investment and consequently identifies land as economically suitable for afforestation. The internal rate of return for the suitable planting areas has been calculated for a single rotation, including carbon. IRRs have been calculated both excluding land cost and including land cost based on recent market values for comparable land. IRRs were calculated assuming ETS participation and a carbon price of $35/NZU.

IRR excluding land cost

IRRs for the suitable planting areas were first calculated, excluding the land cost to provide an expected investment return, excluding land cost. Olssen, Zhang, Evison, and Kerr (2012) applied this methodology to produce a forest profit dataset for New Zealand on the basis that land costs are “endogenous to both forestry returns and other competing returns”. Applying a similar approach relating to land cost enables a direct comparison to the results of this study

The IRRs calculated, excluding land cost ranged from below 0% up to a maximum of 9.8% (Figure 23). On average, the IRR for the suitable planting areas within the Hurunui case study is 7.7%.

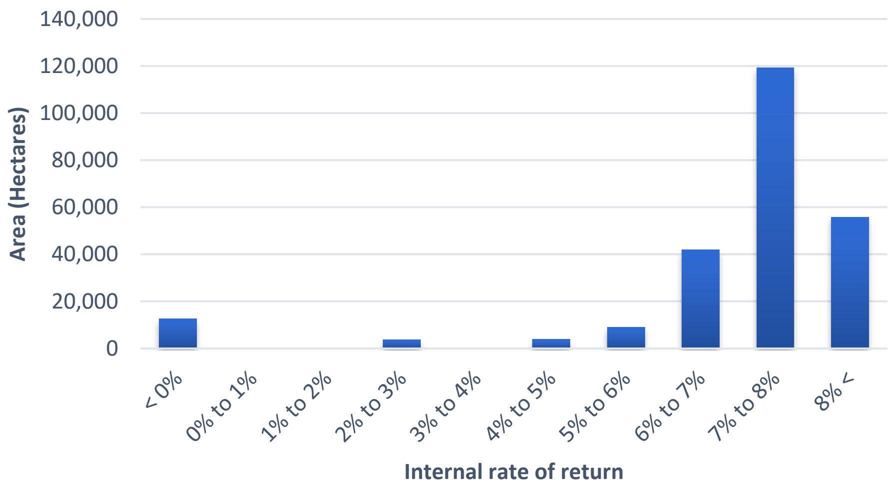


Figure 23: Internal rate of return distribution for suitable planting areas (no land cost)

The average IRR for the suitable planting areas is higher than the 6.11% mean expected forest profit IRR for Canterbury reported by Olssen et al. (2012). This increase in IRR is due to the inclusion of carbon revenue within the economic analysis of the suitable planting areas as the IRRs reported by Olssen et al. (2012) did not include carbon revenue through participation in the ETS. With carbon revenue removed, the IRRs calculated within this study are, on average, 5.5%. The carbon revenue under averaging, a $35 per NZU carbon price and using the lookup table yields accounts for on average 2.2 percentage points of the IRR calculated for the suitable plantable areas.

IRR including land cost

Land costs of $2,727/ha and $5,575/ha were used for the inclusion of land cost within the IRR calculation. These land costs represent the minimum and average recorded recent sales of South Island hill country land (Colliers, 2020).

Land cost of $5,575/ha

The IRRs calculated at a land cost of $5,575/ha for the suitable plantable areas range from below 0% up to a maximum of 6.7% (Figure 24). At a land cost of $5,575/ha, the average IRR for suitable plantable areas within the Hurunui case study was 4.9%.

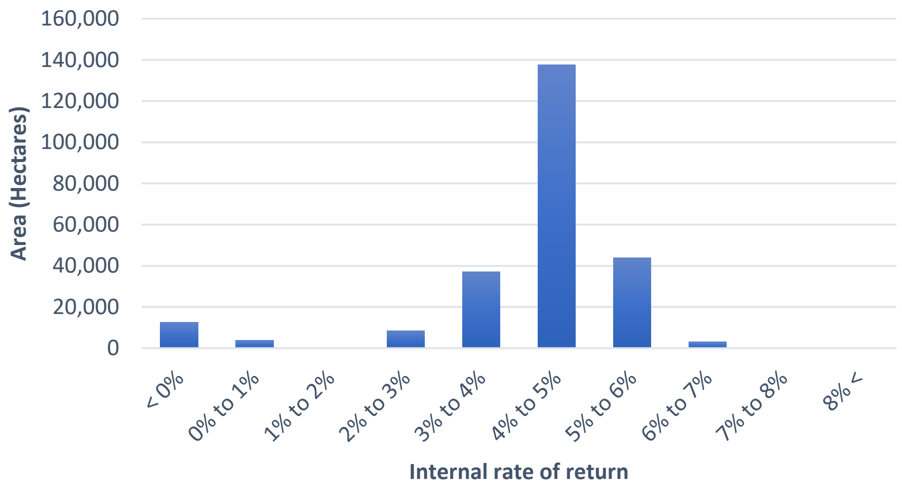


Figure 24: Internal rate of return distribution for suitable planting areas ($5,575/ha land cost)

Commentary on recent sales identified the properties being sold for afforestation within the Canterbury region transacting at a lower per hectare value than the average land cost applied above (Colliers, 2020). The potential for afforestation has been reported to have resulted in significant increases in land costs in the North Island. However, during this period, the value of land purchased for forestry in the South Island has experienced a year-on-year decrease (REINZ, 2019). The use of a $5,575 /ha land cost assumes that the land deemed suitable for afforestation would be purchased at an average market rate for North Canterbury Hill Country land. However, the sales evidence suggests that parties looking to purchase properties for afforestation purposes in Canterbury will target land at the lower end of the land costs listed in recent transactions.

Land cost of $2,727/ha

The IRRs calculated at a land cost of $2,727/ha for the suitable plantable areas range from below 0% up to a maximum of 7.9% (Figure 25). At a land cost of $2,727/ha, the average IRR for suitable plantable areas within the Hurunui case study was 5.9%.

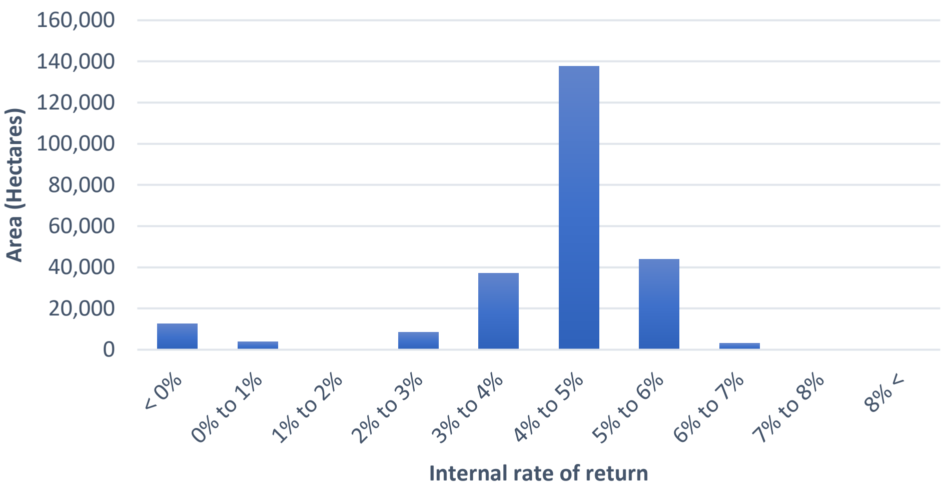


Figure 25: Internal rate of return distribution for suitable planting ($2,727/ha land cost)

Again, the removal of carbon revenue resulted in a decrease in the IRRs calculated at both land costs. With carbon revenue removed the mean IRRs calculated for suitable plantable areas decreased by 1.2 percentage points at a $5,575/ha land cost and 1.5 percentage points at a $2,727 /ha land cost.

Forestry investment return requirement

To explore the areas likely to be economically suitable for afforestation, suitable plantable areas have been limited to only those that produce an IRR of 7% or higher. The use of a 7% return requirement represents the minimum discount rate valuers reported using for small scale forestry under 1000 ha (Manley, 2019). This discount rate represents the assumed required rate of return for investment in commercial forestry. At a land cost of $5,575/ha, there are no suitable plantable areas that meet the 7% return requirement within the Hurunui Case study and are therefore no suitable plantable areas deemed economically suitable at this land cost.

The suitable plantable areas that returned an IRR of higher than 7% at a $2,727/ha land cost are shown below in Figure 26. At this land cost, these areas are deemed to be economically suitable for afforestation. At a land cost of $2,727/ha, there were 9,678 hectares within the Hurunui Case study that exceeded the 7% return requirement. The suitable plantable areas identified as meeting this threshold were mostly above average in terms of productivity, were closer to market, or alternatively, were advantaged by lower harvesting costs.

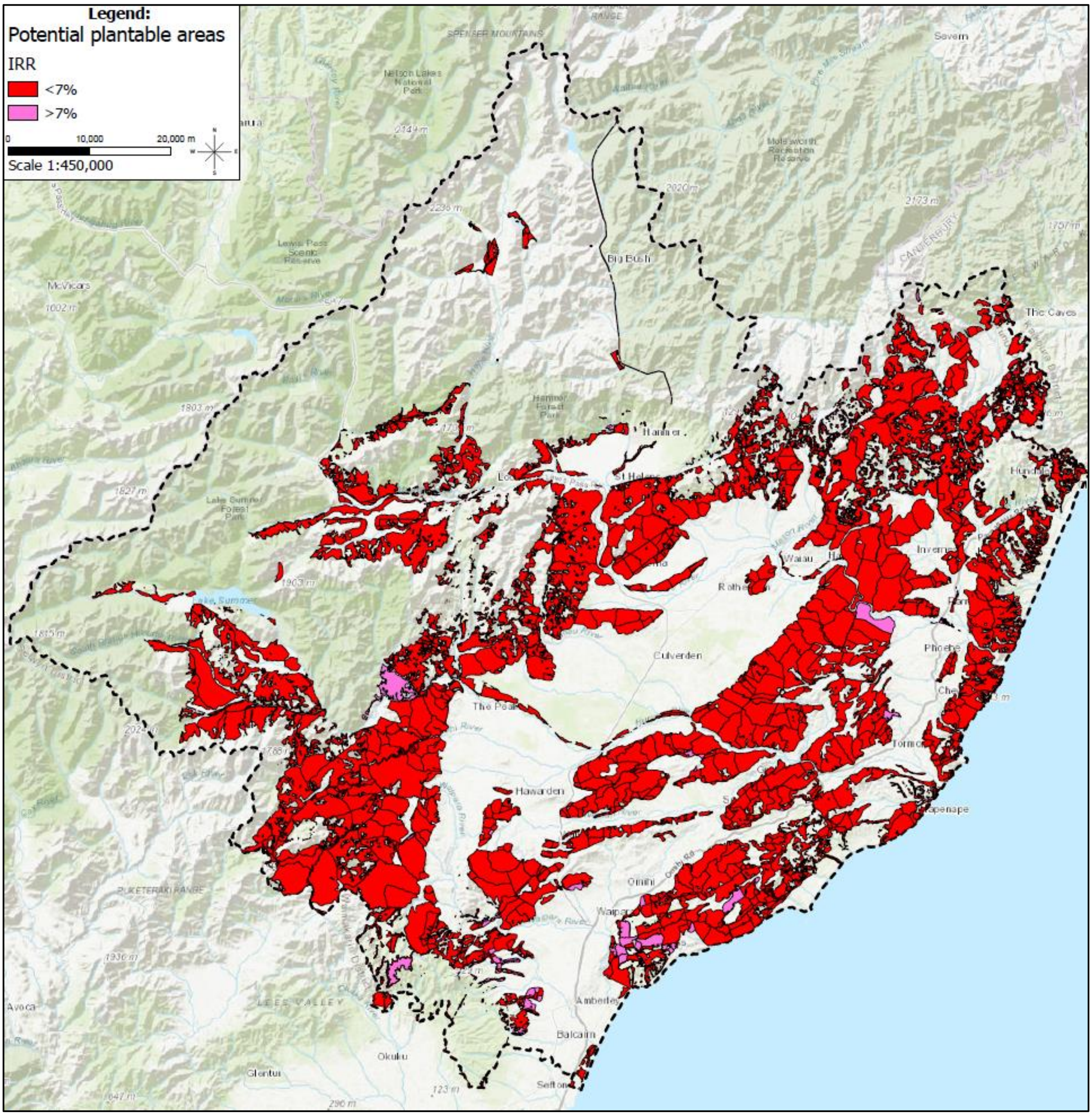


Figure 26: Suitable planting areas with IRR's higher than 7% at a land cost of $2,727/ha

The IRRs reported under both land cost assumptions is consistent with the wide range of total returns for forestry reported by Evison (2018). This paper reported the geometric mean of the total return for the forestry companies studied as ranging from 2.85% to 9.8%. The land deemed economically suitable for afforestation is observed to be influenced by both land cost and the investor's IRR return requirement. Table 11 below shows this interaction and the impact on the land deemed economically suitable for afforestation.

Table 11: Economic suitable land at varying IRR return requirements and land cost

		Land cost ($/ha)							
		$2,000	**$3,000**	**$4,000**	**$5,000**	**$6,000**	**$7,000**	**$8,000**	**$9,000**
IRR return requirement	3%	230,082	230,075	230,071	226,183	223,586	221,668	217,124	214,718
	4%	226,183	223,561	215,820	208,826	192,994	169,068	123,968	100,213
	5%	214,341	190,514	147,110	100,213	54,311	32,229	19,965	7,829
	6%	123,201	62,891	28,727	12,500	3,244	2,325	0	0
	7%	26,656	5,573	2,325	0	0	0	0	0
	8%	2,325	0	0	0	0	0	0	0
	9%	0	0	0	0	0	0	0	0

This table can be used to identify the maximum land cost for the suitable plantable areas within the Canterbury region given the assumed IRR return requirement. At the previous return requirement of 7%, the land cost is limited to $4,000 /ha at which point 2,325 hectares of the suitable planting areas will achieve this. However, if the return requirement was reduced to 6%, the same land area would be economically suitable for afforestation given a land cost of $7,000 /ha.

Economic comparison of competing land use

The above comparison allows conclusions to be made about which suitable plantable areas are likely to be economically suitable from a forestry investment perspective. However, a comparison to the potential alternative land use is required to identify the areas which are likely to be economically superior to the next best alternative land use. Evison (2018) demonstrated that the total investment return calculated is equivalent to the internal rate of return (IRR), for a single period of one year. Therefore, we can compare the total investment return for the primary alternative land use, a typical sheep and beef farm, against the suitable plantable areas IRRs using a $5,575/ha average land. For the economic comparison of the next best alternative land use, the mean total investment return through time for a typical sheep and beef farm is compared against the mean annual rate of growth (IRR) for each suitable planting area.

The suitable plantable areas identified as being above or below the geometric mean total return for a typical sheep and beef farm geometric mean return (Evison, 2018) are shown in Figure 27 below.

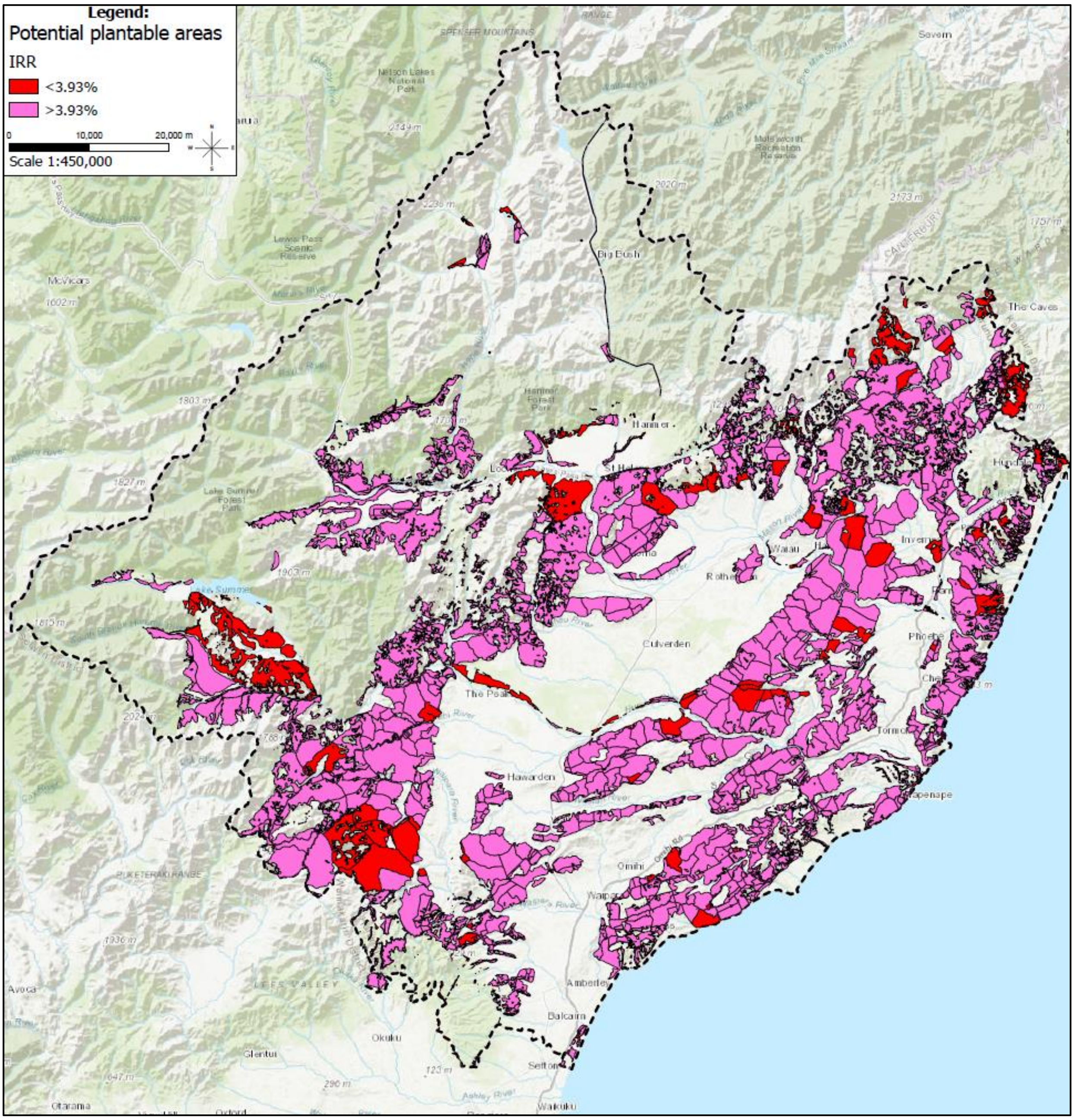


Figure 27: Suitable planting areas with IRR's higher than a typical sheep and beef farm at a land cost of $5,575/ha

Of all the suitable planting areas within the Hurunui case study, 82% provide an economic return under forestry that exceeds the typical sheep and beef farm. Under these assumptions, the land that is economically suitable within the Hurunui TA is 202,100 ha.

The total land identified as suitable for afforestation exceeds the PCE (2019) case study's projections of the percentage of the Hurunui catchment that could be converted to forestry. The PCE case study illustrated the extent of land use change that may be expected given the applied climate policy approaches. The areas deemed as economically suitable within this study's Hurunui case study account for alternative land use change economic returns instead of policy-led drivers. Despite differing primary land use change drivers, the areas deemed as economically suitable for afforestation (Figure 27) aligned with the PCE case study results. The resulting economically suitable planting areas represent 23% of the total TA area and is consistent with the projected conversion of 24% of the Hurunui catchment to plantation forestry cover by 2075 within the PCE (2019) case study.

Figure 27 above assumes that landowners make land use decisions based on the average return over 12 years of a typical sheep and beef farm (Table 12). However, Olssen et al. (2012) identified that landowners have adaptive expectations. That is, the landowners will use past levels of prices and costs to form expectations about potential profits in the future. Therefore, if the landowners chose to make land use decisions based on a point in time return, the result varies significantly as opposed to using the average.

Table 12 and Figure 28 below highlight the effect of using a point in time yearly return when comparing land use on an economic basis. This variation results in the percentage of the suitable plantable areas with IRRs higher than the typical sheep and beef farm total return ranging from 0% to 100%. Comparing the suitable plantable areas with IRRs higher than the typical sheep and beef farm total return on a yearly basis results in a range of between 0 to 246,454 hectares each year being identified as being economically superior to the next best alternative land use.

Table 12: Suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return (Evison, 2018).

Year	Typical sheep and beef farm total return	Suitable planting areas with higher IRR
2005	23.67%	-
2006	2.72%	226,192
2007	4.94%	82,123
2008	-7.91%	246,454
2009	-9.60%	246,454
2010	-0.68%	246,454
2011	4.18%	246,454
2012	8.25%	-
2013	-0.72%	246,454
2014	9.72%	-
2015	11.14%	-
2016	5.55%	24,935
Geometric mean	**3.93%**	**202,100**

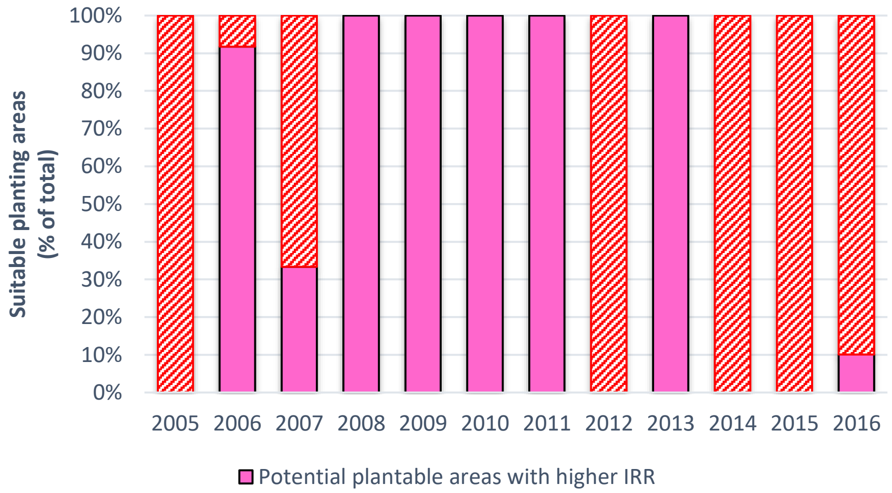


Figure 28: Percentage of suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return

Sensitivity analysis

Manley (2018) identified that carbon price, log price and land cost impacts future afforestation. Within this study, these factors are observed to impact the land deemed economically superior to the next best alternative land use.

CARBON PRICE

Table 13 below shows the impact of a changing carbon price ($/NZU) on the suitable plantable areas with an IRR higher than a typical sheep and beef farm. The land deemed to be economically superior to the next best alternative land use increases as carbon price increases. This is consistent with MacGillivray and Tither (2020), who found that the inclusion of carbon increased the quantity of land that would produce higher returns in production forestry than farming. A carbon price of $81/ NZU is the point at which 100% of the land deemed suitable for afforestation produces a higher IRR than typical sheep and beef farm.

Table 13: Suitable planting areas (Land cost $5,575/ha) with higher IRR than a typical sheep and beef farm total return at varying carbon prices

Carbon Price ($/NZU)	Suitable planting areas with higher IRR (ha)
No ETS	57,355
$10	47,517
$20	106,611
$25	153,860
$30	185,025
$35	202,100
$40	215,645
$45	221,700
$50	226,183
$81	246,454

For Canterbury-based ETS participants, a $10/NZU carbon price does not overcome the cost of being registered in the ETS. At this NZU price, higher IRRs are achieved through assuming the “No ETS’ scenario. At a $12/ NZU price the suitable plantable areas with a higher IRR than typical sheep and beef farm is breakeven with non-ETS participation. The Canterbury/West Coast carbon Look-up Tables for Forestry in the Emissions Trading Scheme have lower carbon stocks than other regions (MPI, 2017). Therefore, it is expected that the break-even NZU price would be lower in other regions that have higher carbon stocks.

The impact of varying land cost ($/ha) and carbon price ($/NZU) is further explored in Table 14 below. At lower carbon prices an increase in land cost has a significant impact on the suitable plantable areas with a higher IRR than a typical sheep and beef farm. However, as the carbon price increases, this impact is reduced, and the impact of an increase in land cost becomes less significant.

Table 14: Suitable planting areas with a higher IRR than a typical sheep and beef farm at varying carbon price and land cost

Carbon Price ($/NZU)	Land cost ($/ha): $2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$8,000	$9,000
No ETS	172,345	132,227	104,841	75,272	48,409	33,928	25,888	18,919
$10	161,898	118,398	94,522	60,065	40,471	29,653	22,286	15,244
$20	204,847	190,627	168,204	123,201	100,213	68,189	44,882	32,234
$30	223,563	215,820	210,295	198,065	172,827	133,489	104,951	76,207
$40	230,075	226,187	223,580	217,147	214,338	199,729	178,594	148,428
$50	230,085	230,085	230,075	226,192	225,220	221,662	215,534	201,264

LOG PRICE

Likewise, a similar effect is observed when a change in operating profit is considered due to variation in log prices. Figure 22 identified a percentage change in the PFO 5 year LPI as having the most significant effect on each suitable planting area's resulting operating profit. Table 15 below shows the impact of an increase or decrease in the PFO 5 year Log Price Index on the suitable plantable areas with higher IRR than a typical sheep and beef farm total return.

Table 15: Effect of a percentage change on the PFO 5 year LPI on the suitable planting areas with higher IRR than a typical sheep and beef farm total return

PFO 5 year LPI	Suitable planting areas with higher IRR (ha)
-30%	2,825
-20%	21,538
-10%	96,825
$120	202,100
+10%	225,067
+20%	230,081
+30%	246,453

A reduction in the PFO 5 year LPI of 30% reduces the suitable plantable areas with a return higher than a typical sheep and beef farm total down to 3,183 hectares. Likewise, a 30% increase in the PFO 5 year LPI of 30% increases the suitable plantable areas with a return higher than a typical sheep and beef farm up to 246,453 hectares. The PFO LPI has varied within the range of +/- 30% over the last five years, reinforcing the impact a point in time economic land use decision can have on the actual land deemed suitable for afforestation (PF Olsen, 2020).

The suitable plantable areas deemed more economic than a typical sheep and beef farm at varying PFO LPI values (land cost = $5,575) is shown below in Figure 29. This effect can be described using a polynomial regression [Percentage of suitable planting areas with higher return = -0.0001(PFO LPI)^2 + 0.0461(PFO LPI) - 3.0587] with an R^2 = 0.926. This equation can be used to model the suitable plantable areas that would be deemed to have the most economic land use of forestry at any given point in time using the PFO LPI at that time.

Figure 29: Effect of changing PFO LPI on the percentage of suitable planting areas with a higher IRR than a typical sheep and beef farm total return

As the above polynomial equation utilizes a “limited dependent variable” there is a risk that prediction variables outside of the useable range will result in invalid results being reported. For the equation of [Percentage of suitable planting areas with higher return = -0.0001(PFO LPI)^2 + 0.0461(PFO LPI) - 3.0587] the prediction range within which the equation is valid is for a PFO LPI between $85 and $163.60; within the model calculating these values as being 0% and 100% respectively. A PFO LPI predicting variable below or above these limits can be assumed to produce a 0% or 100% result respectively.

The impact of varying land cost ($/ha) and log price (PFO 5 year LPI) is shown in table 16 below.

Table 16: Suitable planting areas with a higher IRR than a typical sheep and beef farm at varying PFO 5 year LPI and land cost

PFO 5 year LPI	Land cost ($/ha): $2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$8,000	$9,000
-30%	18,229	6,694	3,616	3,149	2,325	808	0	0
-20%	88,866	58,524	34,398	27,610	18,476	8,254	3,805	3,017
-10%	197,277	184,157	155,324	110,493	87,279	53,227	34,363	26,418
$120	226,184	223,563	217,133	212,007	199,573	175,090	141,475	106,353
+10%	230,083	230,083	229,958	229,876	225,057	222,722	214,811	208,718
+20%	246,454	240,980	233,836	230,083	229,884	229,705	229,704	225,067
+30%	246,454	246,454	246,454	246,454	246,453	240,978	233,637	229,713

It is observed that at lower log prices, an increase in land cost has a notable impact on the suitable plantable areas with a higher IRR than a typical sheep and beef farm. However, as per the carbon price, as the log price increases the impact of a rising land cost is decreased. A 30% increase in log price results in 100% of the suitable planting areas returning a higher IRR than a typical sheep and beef farm up to a land cost of $5,000/ha.

One Billion Tree Funding

The inclusion of the One Billion Trees (1BT) programme funding on the IRRs calculated at a land cost of $5,575/ha for the suitable plantable areas is shown below in Figure 30. Consistent with the previous economic analysis, these IRRs were calculated assuming ETS participation and a carbon price of $35/NZU. The IRRs calculated, including 1BT funding, ranged from below 0% up to a maximum of 7.4% (Figure 24).

Figure 30: Internal rate of return distribution for suitable planting areas including 1BT funding of $1,500/ha ($5,575/ha land cost)

At a land cost of $5,575/ha the average IRR for suitable planting areas within the Hurunui case study was 5.6%, an increase of 0.7 percentage points when 1BT funding was not included. With the inclusion of 1BT funding 223,561 hectares of the suitable planting areas returning a higher IRR than a typical sheep and beef farm.

Marginal delivered cost curve analysis

A marginal delivered cost curve has been calculated for the 246,454 hectares identified within the Hurunui case study as land suitable for afforestation (Figure 15) and the suitable plantable areas within the Hurunui TA with IRR's higher than a typical sheep and beef farm (Figure 27).
Figure 31 below shows this curve based on all suitable land in the Hurunui TA being planted in production forestry and the resulting annual harvest per year of close to 5.5 million m3.

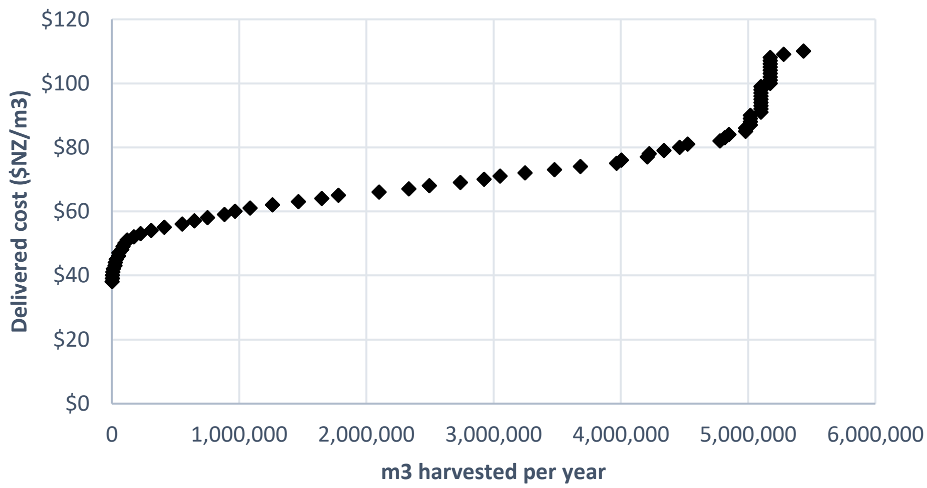


Figure 31: Marginal delivered cost curve for all suitable planting areas within the Hurunui TA

The curve shown in Figure 31 above outlines the marginal delivered cost profile of the volume harvested under this assumption. As indicated by the curve's initial steepness, there is only a small amount of volume with a delivered cost under $\$50/m^3$. From this point onwards the delivered cost steadily increases as the m3 harvested, highlighting the suitable planting areas becoming further from markets and on terrain that incurs higher harvesting costs. This curve follows a linear trend until a delivered cost of $\$85/m^3$ at which point the curve steepens and the harvest volume per year increases minimally despite the higher cost required for these blocks. It will likely be this volume that is most affected by changing market variables given the higher marginal cost required to harvest.

Figure 31 above assumes that all of the Hurunui case study suitable plantable areas would be afforested and in a state of future harvest. However, it is important to explore the likelihood of afforestation based on the land economically superior to the next best alternative land use. Figure 32 shows the marginal delivered cost curve for the suitable plantable areas within the Hurunui TA with IRR's higher than a typical sheep and beef farm. This scenario reduces the resulting annual harvest per year to 4.5 million m3.

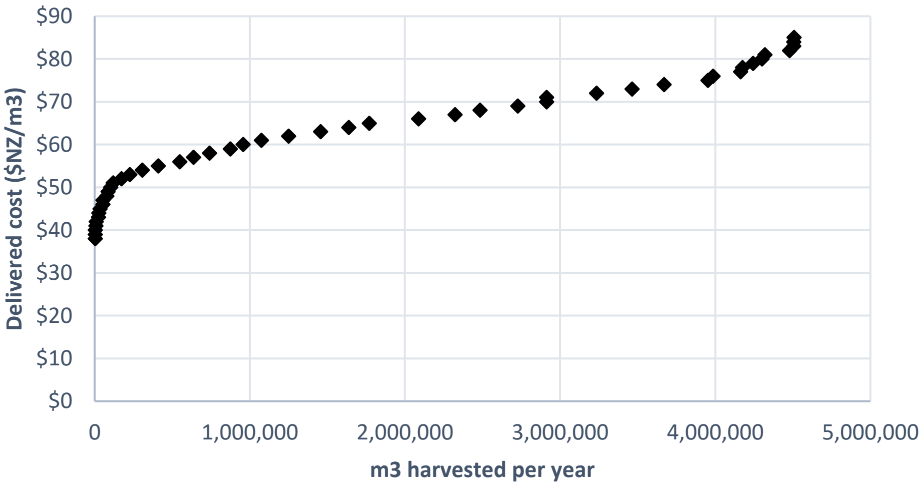


Figure 32: Marginal delivered cost curve for all suitable planting areas within the Hurunui TA with IRR's higher than a typical sheep and beef farm (Land cost = $5,575)

The marginal delivered cost curves in Figure 31 & 32 follow the same initial curve. However, it is observed that as an economic driver requirement is applied the harvest per year excludes the areas with the higher delivered cost. This effect is highlighted in Figure 32 when a return requirement is applied that reduces the annual harvest. In figure 32, the maximum delivered cost only just exceeds $80/m^3; this is much lower than the maximum delivered cost of $110/m^3 in the unconstrained model. There is a point observed for both curves where the delivered cost increases rapidly with minimal increase in volume; this is observed to occur when the delivered wood cost exceeds $80/m^3.

The marginal delivered cost curve highlights the optimisation of production available through economies of scale. If all potential plantable areas were under a single management strategy harvesting would maximize profits up to the point where marginal delivered cost equals marginal revenue. However, the potential plantable areas identified and modelled in the marginal delivered costs curves above were identified as discrete property parcels and are likely individually owned and managed. Therefore, it will be the individuals potential plantable with the highest marginal delivered cost that are impacted the most by changes to harvest costs, transportation costs or log price. The areas with the highest marginal delivered costs will be the first to fail to equal marginal revenue if an increase in harvest costs and transportation costs, or a decrease in log price occurs.

3.4. Conclusions

This study identified that there are over 1.2 million hectares of land deemed suitable for afforestation across the Canterbury region from a biophysical point of view. In absolute terms, the Hurunui and Mackenzie TAs have the highest potential given the total land area suitable for afforestation. These two territorial authorities contain more than half of the land suitable for afforestation. Additionally, recognition was made that the Christchurch City and Waimate TAs present significant opportunities for expanding the area of forestry; both having over 50% of their total land identified as being suitable for afforestation.

The majority of the land identified as suitable for afforestation is currently low-producing grassland under the LUCAS classification and contained within LUC classes 6 & 7. However, there has historically been land within LUC 3 & 4 classes used to establish areas of commercial forestry. If historical planting trends were explicitly used to indicate future land use, then a prediction could be made that 63% of new forest areas would be located on LUC 5, 6 & 7 land and 28% on the higher quality LUC 3 & 4 land. The inclusion of LUC 3 & 4 land increases the land identified as suitable for afforestation across the Canterbury region increased to over 2.2 million hectares. However, LUC 3 & 4 land's underlying land value poses a limitation on the economic suitability for afforestation. Additionally, existing forest land on these LUCs could potentially be converted to an alternative land use, further exacerbating the wood supply problem.

A case study of the Hurunui TA was used to identify the proportion of the land suitable for afforestation that's economically superior to the next best alternative land use. Within the Hurunui TA, there are 246,454 hectares within 1,122 properties identified as suitable planting areas. The average internal rate of return for these suitable planting areas ranged from 4.9% using an average land cost, 5.9% at a minimum land cost and a maximum of 7.7% when the land cost was excluded. There were no suitable planting areas identified that achieved the 7% return requirement for commercial forestry investment at an average land cost of $5,575/ ha. At the minimum land cost assumption of $2,727/ha, 9,678 hectares within the Hurunui TA exceeded the 7% return requirement; 4% of the total land suitable for afforestation. A reduction in the rate of return requirement resulted in a higher land cost being able to be paid, and an increase in the land deemed economically suitable for afforestation.

The suitable plantable areas IRRs were compared against the total investment return for their primary alternative land use, a typical sheep and beef farm, as an economic comparison of the next best alternative land use. 82% of the suitable planting areas within Hurunui provide an economic return that exceeds the typical sheep and beef farm. In total, this equals 202,100 ha of suitable plantable areas within the Hurunui TA that are economically superior to the next best alternative land use. Variation in the typical sheep and beef farm return each year resulted in the land suitable for afforestation exceeding this return ranging from 0% to 100%. This variation highlights the impact that a point in time decision making can have in land use change modelling.

Carbon revenue was identified to positively impact the IRR of suitable planting areas when the carbon price is higher than $12/NZU. As carbon price increased, the suitable planting areas with a higher IRR than a typical sheep and beef farm increased. At an $81/NZU carbon price, 100% of the land deemed suitable for afforestation produced a higher IRR than typical sheep and beef farm.

Log price was also identified to significantly impact the suitable planting areas that produced a higher IRR than typical sheep and beef farm. An LPI range from $85 to $163.60 resulted in the suitable planting areas producing a higher IRR than typical sheep and beef farm varying from 0% to 100%.

An increase in carbon price or log price reduces the impact of a higher land cost on the suitable areas with an IRR than typical sheep and beef farm. An increase in either of these inputs results in afforestation to be economically suitable at a higher land cost. The impact of an increasing carbon or log price has the potential to overcome the land cost limitation previously identified for the LUC 3 & 4 class land identified as suitable for afforestation.

The One Billion Trees programme's funding was observed to impact the IRR positively and increased the land deemed to be economically superior to the next best alternative land use. However, on average landowners who receive 1BT funding would achieve an increase in their IRR of less than 1%.

A marginal delivered cost curve analysis identified an exact point where a higher marginal cost is observed for a minimal gain in volume. While areas meet the economic criteria prescribed in each scenario, it can be assumed that the highest cost marginal areas would likely be the last areas that should practically be planted. For the suitable planting areas within the Hurunui TA with IRRs higher than a typical sheep and beef farm, the marginal cost curve identified a point at an annual harvest of 4.5 million m^3 per year where the marginal gain in harvest volume is impacted by increasing costs. However, the harvest volume from potential plantable areas with the highest marginal delivered costs will be the first to be impacted by an increase in harvest costs and transportation costs, or a decrease in log price.

Expanding the results of the Hurunui case study across all of the Canterbury region proposes that there would be over 50,945 hectares that achieve the 7% return requirement (4% of the total land suitable for afforestation) and 1.04 million hectares (82% of the total land suitable for afforestation) of land that would provide an economic return that exceeds the typical sheep and beef farm. However, this assumes that land use change is driven purely through economic land use choice. Further analysis is required to determine if this economic land use change assumption is correct, or if there is a need to include other factors in order to understand future afforestation levels.

CHAPTER 4: DRIVERS AND BARRIERS OF AFFORESTATION

4.1. Introduction

An analysis of the Survey of Rural Decision Makers 2019 survey data has been used to identify the drivers and barriers of afforestation and explores the potential impact these may have on afforestation within the Canterbury region. Furthermore, a comparison to previous research explored the suitability of applying the SRDM results for projecting afforestation within the Canterbury region.

4.2. Research Methodology

4.2.1. Survey of Rural Decision Makers

The analysis of the drivers and barriers of afforestation has been limited to the relevant questions included in the Landcare Research Survey of Rural Decision Makers (SRDM) data for respondents from the Canterbury region (Stahlmann-Brown, 2019). A survey respondent analysis has been undertaken to identify the drivers and barriers of afforestation.

Description of SRDM (Canterbury) respondents

To undertake an analysis of the data, the characteristics of each survey respondent were summarised and reported. This summary provided a foundation to characterise the average Canterbury-based respondent of the SRDM and facilitated further reporting of deviations from the mean. This analysis reported the age, sex and primary role on the farm for the 556 respondents whose primary farm was located within the Canterbury region. Additionally, the survey respondents' primary farm characteristics were summarised and reported. This summary included the location of the primary farm, property type primary activity and the land area (ha) of their property.

Drivers and barriers of afforestation

The drivers for afforestation were separated into past afforestation and future afforestation drivers. The respondents who answered Yes to SRDM Q99 "Has the total amount of land planted in trees (net stocked forest area) on your farm increased in the recent past?" were classified as respondents who had undertaken past afforestation. Respondents who answered Yes to SRDM Q99 (regarding the total amount of land planted in trees on their farm) “Will it increase in the near future?” were classified as respondents who were planning on undertaking future afforestation.

Past planting drivers

The drivers of past afforestation were identified using SRDM Q100 “Which of the following are the main reasons for your decision to plant trees on your farm in the recent past?”. An F-Test Two-Sample for Variances test was undertaken to explore if there was a statistical significance in the difference in past planting drivers of respondents classified as commercial or lifestyle properties. The foremost driver of past afforestation was identified using SRDM Q101 “Among the main reasons for the decision to plant trees on your farm in the recent past, which was the single most important?”.

Future planting drivers

The drivers of future afforestation were identified using SRDM Q103 “Which of the following are the main reasons for your decision to plant trees on your farm in the next two years?”. An F-Test Two-Sample for Variances test was undertaken to explore if there was a statistical significance in the difference in future planting drivers of respondents classified as commercial or lifestyle properties. The foremost driver of future afforestation was identified using SRDM Q104 “Among the main reasons of the decision to plant trees on your farm, which is the single most important?”.

Species choice

The species choice of future planting within the next two years planting was identified using SRDM Q102 “Of the land that you intend to plant trees in over the next 2 years, what % of the total area do you expect to plant with each of the following types of trees?”. The species choice of future planting was summarised as the average percentage of area that respondents expected to plant within each different species. An F-Test Two-Sample for Variances test was undertaken to explore if there was a statistical significance in the difference in the species choice of future planting between respondents classified as commercial or lifestyle properties.

Barriers to afforestation

The commercial property respondents who reported they had land that could potentially accommodate planting new land in trees but were not planning on undertaking future planting were identified as respondents who answered No to SRDM Q99 (regarding the total amount of land planted in trees on their farm) "Will it increase in the near future?" alongside respondents who answered Yes to SRDM Q105 "Could your land and commercial enterprise potentially accommodate planting new land in trees if you decided to in the future?". The specific barriers to afforestation were further identified using SRDM Q106 "What are the main reasons that you do not plan to plant new land in trees in the short-medium term?".

Comparison of survey results

Finally, a literature review of comparative research was undertaken to evaluate the conclusions made in this study against prior research. The review explored variances in the drivers for land use change previously reported in literature. This comparison tested the validity of the responses of the Survey of Rural Decision Makers against comparable studies.

4.3. Results and Discussion

4.3.1. Survey of Rural Decision Makers

Description of SRDM (Canterbury) respondents

The characteristics of the Canterbury subset of the SRDM respondents are shown in Table 17 below, alongside the characteristics of their primary properties in Table 18 (Stahlmann-Brown, 2019).

Table 17: Characteristics of study respondents (n = 556)

Characteristic	***%***	***n***
Age		
15 – 24	*0.2%*	1
25 – 34	*2.5%*	14
35 – 44	*10.8%*	60
45 – 54	*15.5%*	86
55 – 64	*26.4%*	147
> 65	*27.9%*	155
No response	*16.7%*	93
Sex		
Male	*57.9%*	322
Female	*27.9%*	155
Prefer not to answer	*0.4%*	2
No response	*13.8%*	77
Primary role on the farm		
Farm owner/joint-farm owner	*35.3%*	196
Equity partner/partnership	*1.3%*	7
Farm manager/operations manager/supervisor/CEO/etc	*3.4%*	19
Share milker	*1.1%*	6
Representative of a Māori trust/incorporation	*0.0%*	0
Representative of a family trust or other trust	*1.6%*	9
Leasee	*2.2%*	12
Other (please specify)	*0.9%*	5
N/A (Property type = Lifestyle)	*48.6%*	270
No response	*5.8%*	32

In total there were 556 respondents whose primary farm was located within the Canterbury region. Over half of those surveyed (54%) were above the age of 55, with only 3% of the survey respondents under the age of 35. A higher percentage of male respondents was observed (58%) than female respondents (28%). The respondents of the SRDM are consistent with the typical distribution of farmer characteristics in New Zealand (Statistics New Zealand, 2015, 2018).

Table 18: Characteristics of study respondents primary farm (n = 556)

Characteristic	%	n
Location of primary farm		
Kaikoura	*2%*	9
Hurunui	*14%*	78
Selwyn	*26%*	147
Waimakariri	*22%*	123
Christchurch	*5%*	29
Ashburton	*12%*	64
Timaru	*11%*	62
Mackenzie	*3%*	14
Waimate	*5%*	27
Waitaki	*1%*	3
Property type		
Commercial	*41%*	230
Lifestyle	*49%*	270
Neither	*10%*	56
Primary activity		
Grazing livestock that are not owned by the farming business	*3.2%*	18
Farming sheep and/or beef	*14.9%*	83
Raising and/or finishing prime cattle, including bull beef	*4.5%*	25
Dairying	*9.7%*	54
Deer farming	*2.5%*	14
Pig farming	*0.4%*	2
Other farmed livestock	*0.5%*	3
Growing flowers, bulbs, nursery crops, and hops	*0.9%*	5
Wine grape production	*0.4%*	2
Growing other fruits, nuts, and edible tree crops	*0.4%*	2
Exotic forestry for commercial harvest	*3.1%*	17
Farm-based tourism	*0.2%*	1
Arable farming	*4.5%*	25
Vegetable production	*0.5%*	3
N/A (Property type = Lifestyle)	*48.6%*	270
No response	*5.8%*	32
Land area (ha)		
Min		1
Average		307
Max		12000

The spread of respondents with their primary farm within the Canterbury region is observed to cover all TAs. Respondents were balanced between commercial (41%) and lifestyle (49%) property types. There was a wide variation in the size of the respondent's primary farm, but on average, the mean farmland area for SRDM respondents was 307 hectares.

The responses for the primary role on the farm and properties primary activity exclude lifestyle property respondents. Farm owner/joint farm owner was the primary role reported by 77% non-lifestyle respondents. The primary activity reported was farming sheep and/or beef followed by Dairying. 6.1% of non-lifestyle respondents reported their primary activity as being exotic forestry for commercial harvest.

4.3.2. Agent drivers & barriers

The scope of this analysis has been limited to the results attainable from the Stahlmann-Brown (2019) SRDM data for respondents from the Canterbury region. Using this data will enable an identification of the potential barriers and leverage points that may impact afforestation in Canterbury. Furthermore, these barriers and drivers will allow conclusions to be made regarding the likelihood of the land suitable for afforestation being planted in the future.

Afforestation drivers

The drivers of afforestation have been explored to enable conclusions to be made on the likelihood of the suitable land being planted in commercial forestry species. A profit maximisation led decision-making assumption was used when identifying the land economically suitable for afforestation in the Hurunui case study. Identifying the drivers for afforestation is essential to investigate if profit maximisation drives land use change, or if there are alternative drivers that rural landowners are influenced by. To identify these drivers, the respondents have been separated into past and future afforestation drivers.

Past planting drivers

The respondents identified drivers for past afforestation are shown below in Figure 33. In total, 177 respondents (32%) reported that the total amount of land planted in trees on their farm had increased within the last ten years (Appendix C - Table 2).

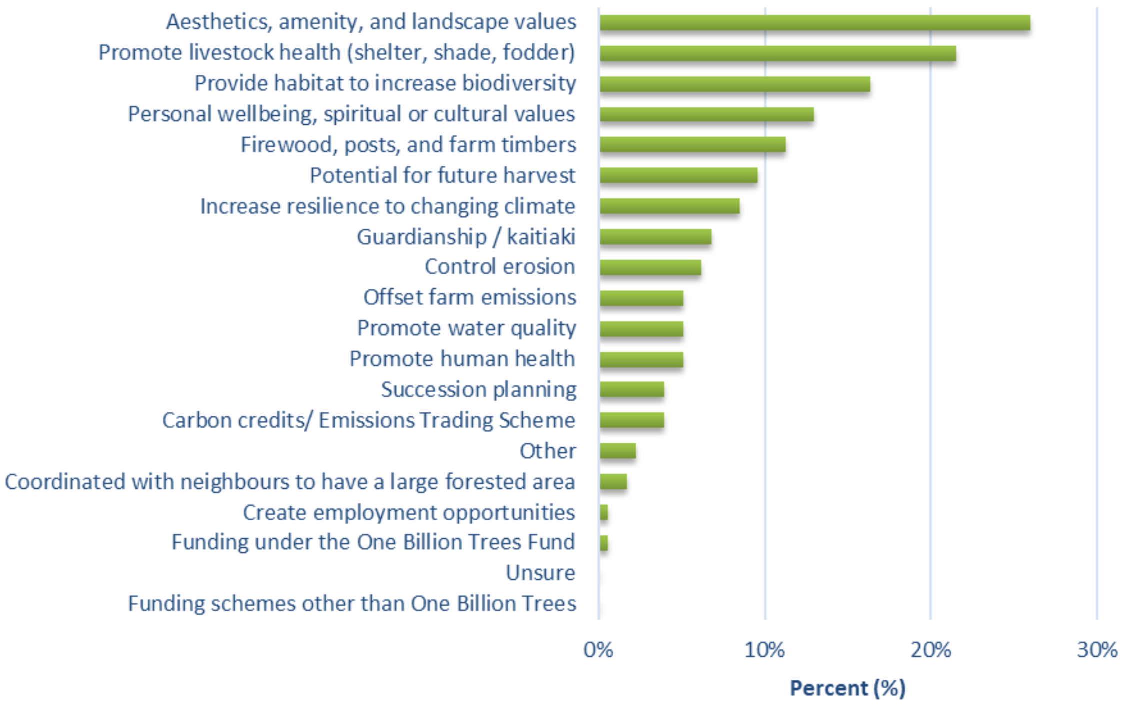


Figure 33: Past planting drivers

The ranking of these drivers provides an insight as to why the previous planting was undertaken on the respondents' properties. The top-ranking drivers for past afforestation were aesthetics, amenity, and landscape values, promoting livestock health, and to provide habitat to increase biodiversity. Under 10% of the respondents reported the potential for future harvest as a driver of past afforestation. Only 4% reported carbon credits/ Emissions Trading Scheme as a driver of this afforestation.

The respondents have been separated into commercial or lifestyle property types (Figure 34 & Appendix C tables 3 & 4). There was no difference in the top three most important drivers when comparing commercial and lifestyle properties. Both commercial and lifestyle property owners reported their primary drivers as being aesthetics, amenity, and landscape values, promoting livestock health, and to provide habitat to increase biodiversity. However, lifestyle properties did report personal wellbeing, spiritual or cultural values and the potential for firewood, posts, and farm timbers as being more significant drivers than those respondents with commercial properties. The difference in past planting drivers of respondents classified commercial or lifestyle properties are deemed statistically significant with when comparing these two populations (p = .02).

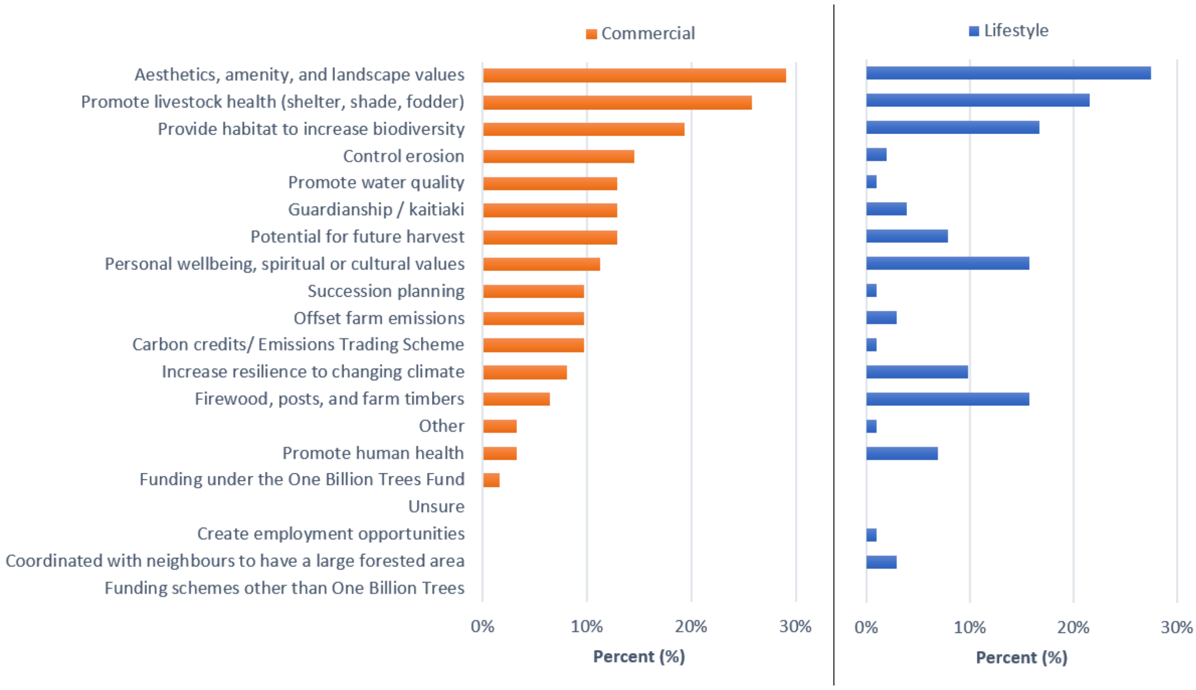


Figure 34: Past planting drivers - Commercial vs Lifestyle

A higher percentage of commercial property respondents reported the potential for future harvest (13% vs 8%) and carbon credits/ Emissions Trading Scheme (10% vs 1%) as a driver for afforestation compared to lifestyle properties. The potential to offset farm emissions was a more common driver for commercial property owners with 10% of commercial respondents reporting this as a driver against only 3% of lifestyle respondents.

When asked to rank which of these drivers was the single-most-important driver for past afforestation, 66% of respondents did not provide a response (Table 19). This ranking suggests that there was no identifiable single-most important reason for undertaking the afforestation when reflecting on past planting. A lack of a single most important driver suggests that the decision was made for multiple reasons. Among the people who responded, aesthetics, amenities, and landscape values were the highest-ranked, consistent with the top driver reported in Figure 34 above.

Table 19: Respondents top 5 most important past planting drivers (Full list in Appendix C - Table 5)

No response	Aesthetics, amenity, and landscape values	Providing habitat to increase biodiversity	Potential for future harvest	Promote livestock health
66%	12%	5%	4%	4%

Future planting drivers

The respondents identified drivers for future afforestation are shown in Figure 35 below. In total, 161 respondents (29%) reported that the total amount of land planted in trees on their farm will increase in the next two years (Appendix C - Table 6). These drivers represent the respondent's current reasons for undertaking future planting on their properties. While the past planting drivers offer insight into historical reasoning, these drivers provide context as to why future afforestation is currently being chosen.

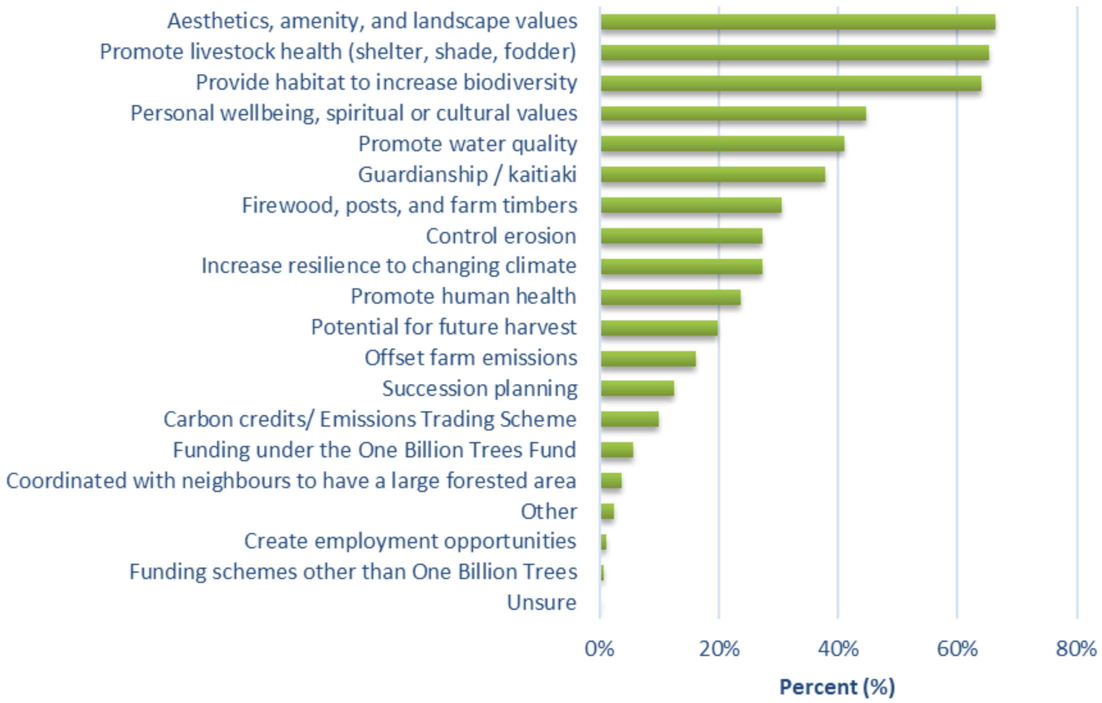


Figure 35: Future planting drivers

The top-ranking drivers for future planting were aesthetics, amenity, and landscape values, followed by promoting livestock health and providing habitat to increase biodiversity. The top four highest-ranked drivers for future afforestation were consistent with the same four drivers ranked as the highest for respondents' past planting drivers.

The number of respondents reporting the potential for future harvest and carbon credits/ Emissions Trading Scheme as a driver of future afforestation was lower than the past planting drivers. 5% of respondents reported the potential future harvest and 1% reported carbon credits/ Emissions Trading Scheme as drivers for future planting. However, there was an increase in respondents reporting that offsetting farm emissions as a driver of future planting (16%) compared to past planting drivers (5%).

The future drivers have also been separated by respondents with primary farms classified as commercial or lifestyle properties (Figure 36 & Appendix C - tables 7 & 8). Consistent with the past planting drivers, there was no difference in the top three most important drivers between commercial and lifestyle properties. However, lifestyle property owners identified a different top driver with promoting livestock health as the most important of these three drivers of future planting. The difference in future planting drivers of respondents classified commercial or lifestyle properties are deemed statistically significant when comparing these two populations ($p = .03$).

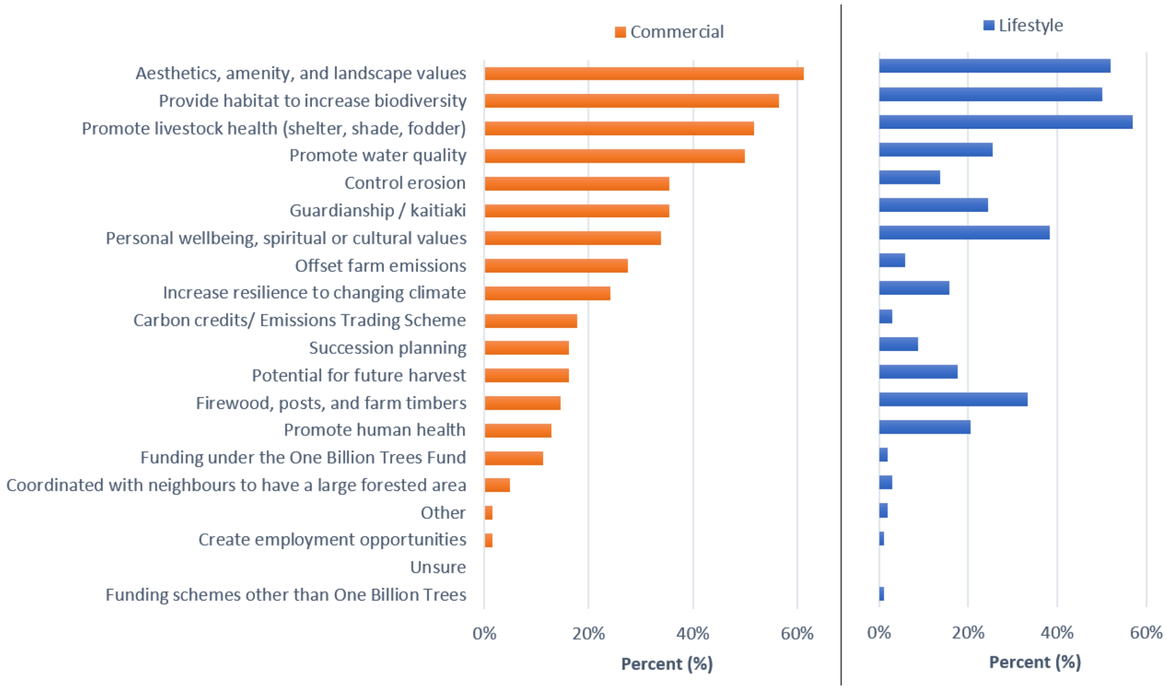


Figure 36: Future planting drivers - Commercial vs Lifestyle

Consistent with the past planting drivers, lifestyle property respondents reported personal wellbeing, spiritual or cultural values and the potential for firewood, posts, and farm timbers as being more significant drivers than commercial property respondents. A difference was observed compared to the past drivers with a lower percentage of commercial property respondents reporting the potential for future harvest as a driver for afforestation than lifestyle properties. Again, a higher percentage of commercial property respondents reported carbon credits/Emissions Trading Scheme (18% vs 3%) as drivers for afforestation compared to lifestyle properties. Consistent with past planting drivers, a higher percentage of commercial property respondents identified the potential to offset farm emissions as a driver of future planting. A total of 10% of commercial property respondents identified this as a driver compared to 3% of lifestyle property respondents.

The respondents undertaking planting within the next two years were also asked to rank which of these drivers was the single-most-important driver influencing their afforestation decision. Table 20 below summarises the top 5 most important drivers of future planting.

Table 20: Respondents most important future planting driver (Full list in Appendix C - Table 5)

Providing habitat to increase biodiversity	Aesthetics, amenity, and landscape values	Promote livestock health	Guardianship/kaitiaki	No response
21%	16%	13%	12%	9%

Providing habitat to increase biodiversity was the single-most-important driver reported by respondents for future planting. This was followed by aesthetics, amenity, and landscape values and promoting livestock health. These three drivers were consistent with the ranking of the most important drivers of past planting in Table 19. 12% of respondents reported Guardianship/kaitiaki to be the most important driver of their future planting. This was a change when compared to the most important drivers of past planting, where not a single respondent identified this as an important driver. The potential for future harvest was not within the top five most important drivers of future planting. However, a similar percentage of respondents selected this as their most important driver for both past and future planting.

A smaller percentage of the rural landowners who intended to plant within the next two years did not provide a response (9%) than when compared to the past planting respondents (66%). This identifies that respondents planning term future planting have a more identifiable most important drivers than those who have undertaken past planting. This is likely due to the decision being a recent land use change decision instead of asking respondents to reflect on a longer time period.

Species choice

Figure 37 below displays the average percentage of species for the total area of trees that respondents expected to plant over the next two years.

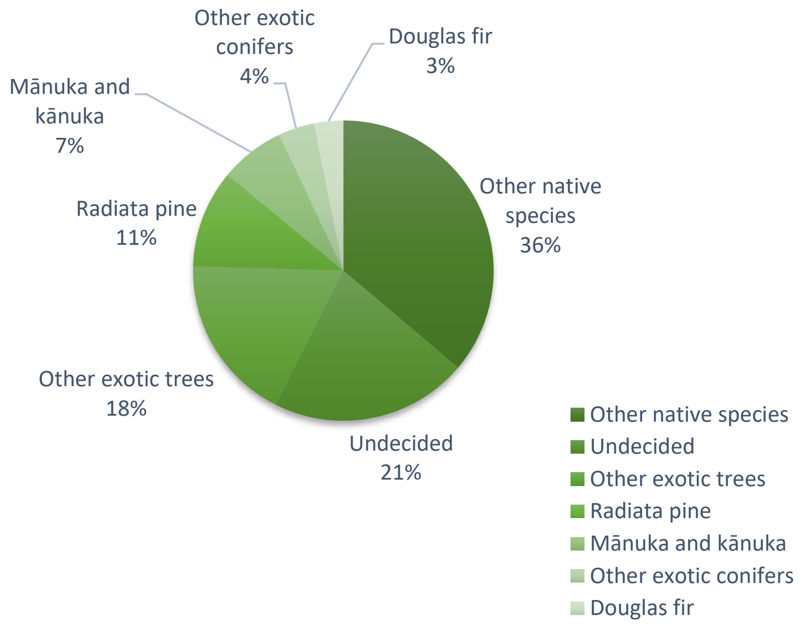


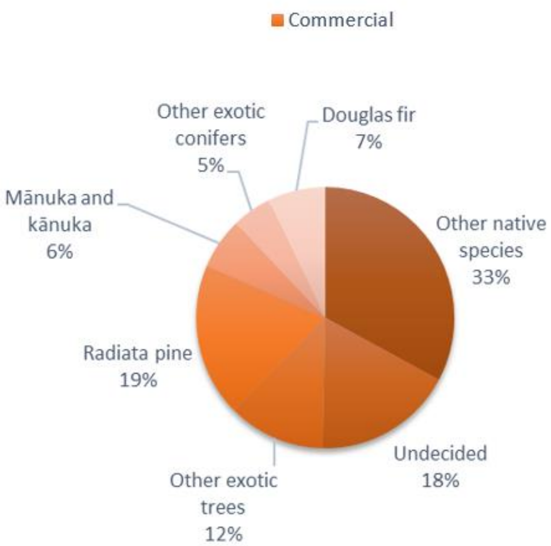
Figure 37: Average species percentage of the total land area of future planting

The drivers for future planting are further reflected in the species choice by respondents. Other native species was the dominant choice by respondents with an average of 36% of the area expected to be this type of planting. The respondent's species selection is consistent with the primary drivers identified for future planting. These drivers prioritised providing habitats to increase biodiversity, promote livestock health and aesthetics, amenity, and landscape values (Figure 35 & Table 20). These drivers align with the respondents undertaking future planting preferences for planting other native species instead of production forestry species.

The potential for future harvest was not identified as a significant driver for future planting, with just 20% of respondents identifying this as a driver (Figure 35). The National Exotic Forest Description identifies Radiata pine and Douglas fir as the most dominant production forestry species for harvest within New Zealand (MPI, 2019b). However, for respondents, these were not the dominant species identified for future planting with on average 11% of area expected to be planted in Radiata pine and 3% in Douglas fir. It is expected that there would have been a stronger preference towards traditional New Zealand production forestry species if the potential for future harvest was a more highly ranked driver.

Based on the drivers of this future planting the respondents who identified other exotic trees as their expected future planting may be looking to establish a species such as Poplars to promote livestock health (shelter, shade, fodder). Poplars are commonly used within New Zealand farming for shelter and potential sources of alternative fodder for livestock, particularly during droughts (Ball, Carle, & Del Lungo, 2005; Kemp, Mackay, Matheson, & Timmins, 2001).

The difference in the species choice of respondents classified as either commercial or lifestyle properties is deemed statistically significant when comparing the two populations (p = .045).



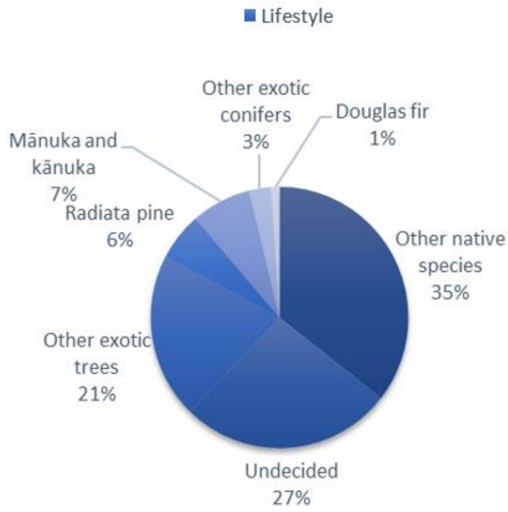


Figure 38: Average species percentage of the total land area of future planting - Commercial vs Lifestyle

The most significant difference in species choice between commercial and lifestyle respondents was the percentage selecting commercial forestry species (Figure 38). On average, commercial property respondents indicated 26.3% of future planting would be commercial forestry species compared to 7% of lifestyle respondents. This observation contrasts the reported drivers for future afforestation. A lower percentage of commercial property respondents reported the potential for future harvest as a driver for afforestation compared to lifestyle property respondents. However, a higher percentage of commercial property respondents reported carbon credits/Emissions Trading Scheme as a driver for afforestation compared to lifestyle property respondents. This indicates that species choice for these respondents is likely driven by the annual carbon revenue achievable by planting these fast-growing species instead of the lump sum future harvest revenue.

Afforestation barriers

In total, 82 respondents reported they had land that could accommodate planting trees but were not planning to undertake future planting. Figure 39 below shows the main reasons commercial property respondents reported that they did not plan to plant new land in trees in the short-medium term.

Figure 39: Barriers to future planting

The primary barrier for afforestation is opportunity cost, with 70% of these respondents identifying this as a barrier. This result is consistent with Ryan's (2012) findings that concluded the gain from forestry income is not enough to counter the decrease in agricultural income, perceived decline in wealth, and the loss of utility derived from farming the land. This study reported that farmers tend to act rationally when comparing farming for forestry, even if the potential income from forestry is higher. The respondents reporting opportunity cost a barrier of future planting are likely identifying the impacts that afforestation would have on their farming system overall. Jaffe (2017) identified that decisionmakers' cognitive processes could lead to deviations from optimal decision making. Given the primary drivers and species choice for future afforestation being targeted towards non-commercial forestry species, there may be a disconnect between the most economically-optimal future planting option, plantation forestry, and the next-best land use being a Sheep and Beef farm.

Opportunity cost was followed by expense/financial barriers and uncertainty about best land use options as the next most significant barriers to future planting. In a US-based study, Valdivia, Barbieri, and Gold (2012) identified the expense of establishing or managing trees, the time required to manage, and the lack of tree management experience as the most perceived barriers limiting afforestation on farms. Burrows, Wakelin, Quinn, Graham, and Mackay (2018) reported a similar trend in that initiatives to increased sequestration hinged on favourable cost/benefit ratios. These comparisons are consistent with the barriers identified in this study outside of the primary barrier of opportunity cost.

In total, 16% of respondents reported negative perceptions about tree planting and forestry as a barrier to future planting. Petty, Priester, and Brinol (2002) provided insight into how the media can influence the public's attitudes and behaviours. Based on their findings, negative perceptions of forestry can be a barrier to future planting. Bayne, Edwards, and Payn (2019) reported that the impacts from significant weather events on forests and forestry operations, downstream infrastructure, and land and beaches have been of significant interest to local and national media. Reporting in the media has focused on forestry operations, local planning and consent decisions, and the experiences of the people affected. This research identified the forest sector as being seen to be the key causer of these problems. It was also acknowledged that there is an existing goodwill relationship with the forest sector, and this was reflected in what was reported in the media. The media commonly reported events were a natural occurrence or an act of God because of extreme weather within the regions of concern. However, these headlines typically expressed the outcomes as a forestry issue as opposed to a landscape issue. The 16% of respondents that reported negative perceptions about tree planting and forestry as a barrier to future planting have likely been influenced by the perceptions of forestry in the media, and this has limited future planting.

Agent characteristics

An agent analysis of the SRDM respondents has been undertaken to identify the characteristics of the agent most likely to undertake future afforestation. Agent characteristics have been identified, analysed and summarised using the respondents that were planning future planting. This methodology provides an opportunity to identify the characteristic of an average agent and compare the difference in characteristics of the agents planning future planting.

Future planting

The difference in the characteristics of respondents who reported future planting would be occurring within the next two years are shown in Figure 40 and 41 below.

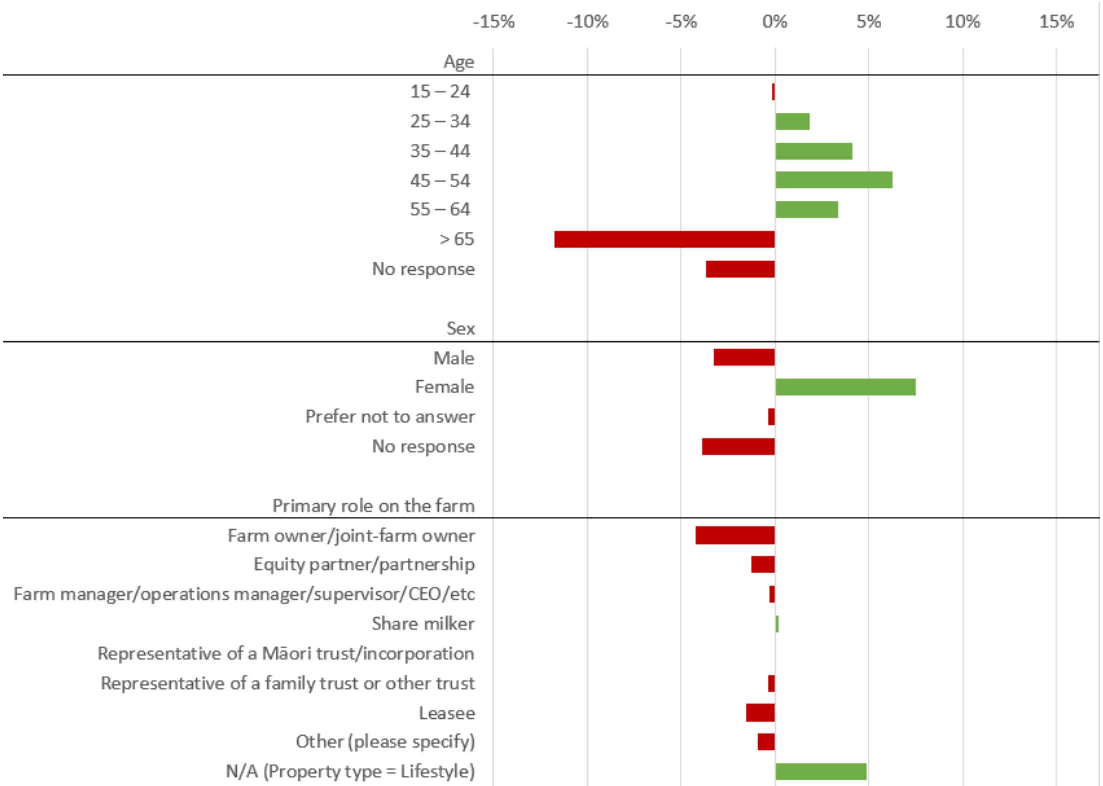


Figure 40: Difference in agent characteristics (expressed as a %) of future planting respondents compared to the average agent

Respondents who reported planning future planting are predominantly within the younger age classes with a notable decrease in the percentage of responders over 65. Additionally, there was a higher number of respondents identifying as female within those who were planning future afforestation.

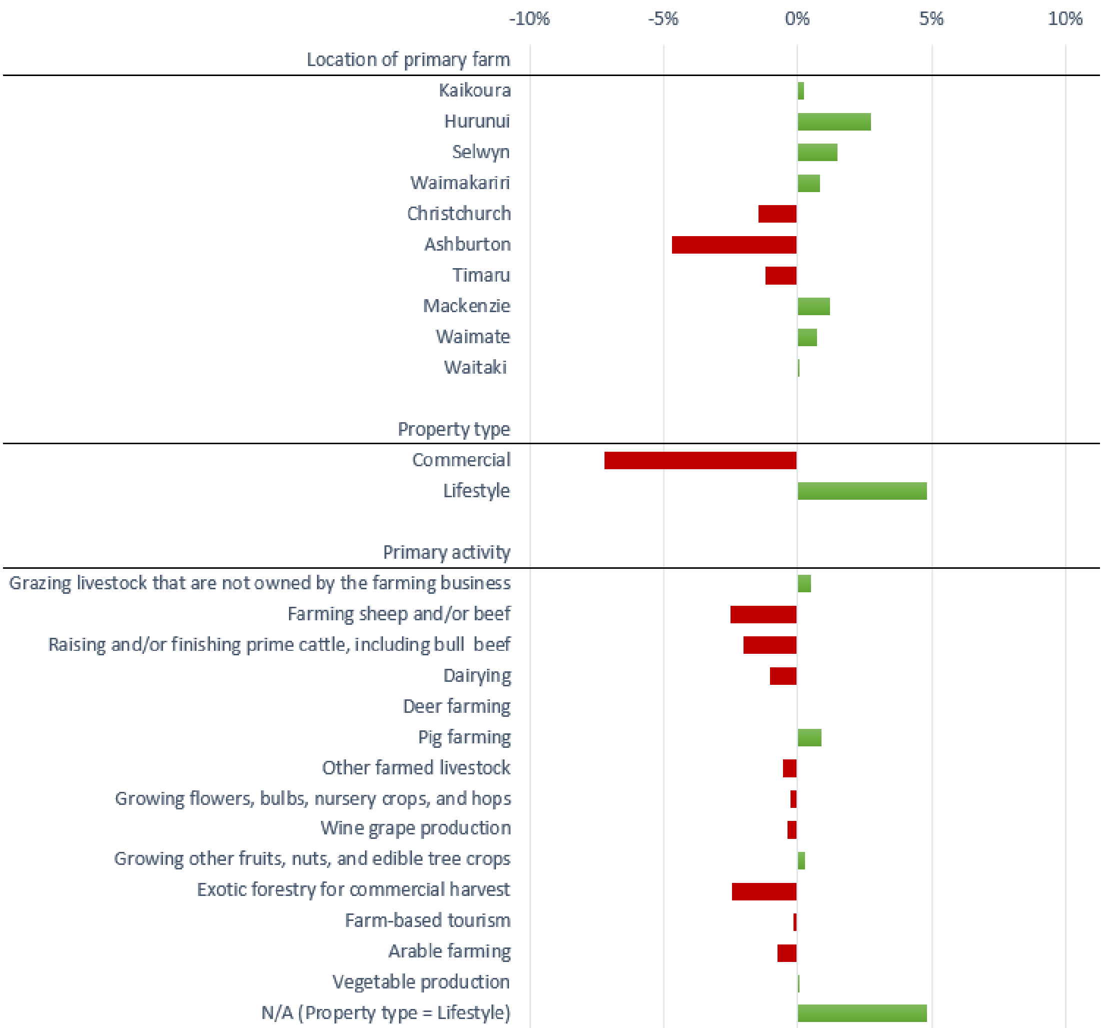


Figure 41: Difference in primary farm characteristics of future planting respondents compared to the average agent

As shown in Figure 41 above, there was a minor difference observed between TAs. Respondents from the two TA with the largest areas suitable for afforestation (Hurunui and Mackenzie TAs) were identified to be more likely to undertake future planting than an average agent. When comparing commercial and lifestyle properties, this study identified there was a clear trend—that lifestyle property owner respondents were more likely to undertake future planting than their commercial property owner counterparts. When identifying respondents' primary activity, this study identified a decrease in the percentage of respondents within multiple categories who were planning future afforestation. The largest decrease was for respondents within the farm owner/joint farm owner category. Respondents who reported their primary activity as exotic forestry for commercial harvest were less likely to undertake future planting than the average agent. It is likely to these respondents having already maximised their properties potential for forest area due to the commercial nature of their forestry primary activity.

4.3.3. Comparison of survey results to the results of past studies

A comparison of previous research was undertaken to explore the suitability of applying the SRDM results to forecast the likelihood of afforestation within the Canterbury region. The purpose of this comparison is to identify if the results attained from the SRDM align with the reported drivers for land use change of landowners in previous research. This analysis is essential to explore if the specific respondents of the SRDM can be extrapolated and used as an assumption to forecast the potential afforestation within the Canterbury region. Burrows et al. (2018) identified that rural decision making had been the subject of widespread research. However, these drivers and barriers change over time, and when research becomes dated, it can be challenging to use this information to predict future behaviour. Given the recent timeframe that this survey was undertaken, it provides a point in time insight into the current drivers and barriers of afforestation.

For any form of agent-based analysis adequate data is required to ensure the results produced provide a satisfactory alternative to the mathematical parameter-based models generally applied in land use change science (D. Brown et al., 2004; Grimm et al., 2005; Verburg, 2006). The exact response rates for the 2019 SRDM were unavailable for this study. However, table 21 below shows the sample, completion rates and response rates for the previous SRDM in the Canterbury region. A total of 2,821 email addresses were accessed using AgriBase, an AssureQuality managed commercial database of New Zealand's rural properties. Overall a 10% response rate was observed, resulting in 283 surveys being completed.

Table 21: Sample, completion rates and response rates ***(P. Brown et al., 2013)***

Region	Primary Sample	Surveys begun	Surveys completed	Completion rate	Final response rate
Canterbury	2821	424	283	66.7%	10.0%

Achieving adequate participation for web surveys is an acknowledged issue as they tend to suffer from lower response rates than other survey modes (Fricker, Galesic, Tourangeau, & Yan, 2005). Sauermann and Roach (2013) report that low response rates reduce statistical power and may affect the validity of survey results. Furthermore, small samples not only limit the econometric techniques that can be applied to the data, but may also affect the credibility of research results in the eyes of reviewers and readers (Rogelberg & Stanton, 2007).

The previous SRDM response rate is observed to be lower than a typical web-based survey response rate (Cook, Heath, & Thompson, 2016; Kaplowitz, D Hadlock, & Levine, 2004; Shih & Fan, 2008). Fowler Jr (2013) firmly stated that respondents to a survey with a 20% or less response rate should be thought of as self-selected and unlikely to yield any credible statistics about the characteristics of the population as a whole. Therefore, to validate the representativeness of the SRDM survey responses, it is essential to compare these results with past research and the drivers and barriers of afforestation reported. This comparison sought to confirm if the results attained from the smaller subset of a potential 10% of respondents reflects the drivers of the larger population. Consequently, a conclusion can be made regarding the robustness of the results attained using the SRDM data.

In a broader land use change study, an analysis of the drivers and barriers of land use change were reported by Journeaux et al. (2017). This study identified a wide range of factors that influence land use change: biophysical, economic, technological change, societal pressures, licence to farm and personal factors. This study concluded that as drivers and barriers, all these factors interact in different ways and usually never in the same combination. When comparing the results attained from the SRDM data with previous research, it is important to acknowledge the respondents' views and the perspective they provide. As concluded by Journeaux et al. (2017), the barriers and drivers of afforestation can interact in various different ways. This reported variation supports the comparison of similar research to ensure that the drivers and barriers for afforestation identified using the SRDM data are consistent with land use change trends in general.

Rhodes, Novis, Enters, and Durst (2004) identified a range of policy instruments that increased forestry's comparative advantage. However, in a more specific analysis, it was concluded that the overriding stimulus for commercial timber planting was price driven and the perceptions of future price developments. A similar survey of small landowners indicated that their primary reason for owning plantation forest was income from timber, further supporting the importance of financial drivers for afforestation (Rodenberg Ballweg, 2013). This research highlights a difference to the primary afforestation drivers identified using the SRDM data. The number of SRDM respondents reporting the potential for future harvest as a driver of past and future afforestation was not a significant driver with just 10% and 5% respectively reporting this as a driver.

Fairweather (1992) undertook a regional pilot survey of farmers’ decision making processes regarding trees on their farms. This study suggested that economic factors played a significant part when farmers were deciding to plant trees on their farms. However, it was noted that financial returns from forestry may not always be significant as a motivation for afforestation. The analysis of potential afforestation within the Hurunui TA in this study was based on assumptions relating to biophysical suitability and best economic returns. As per these assumptions, afforestation can be viewed using economic drivers commonly used in a commercial forestry perspective. However, consideration needs to be made to how farmers and rural landowners view and analyse forestry and if these views are similar to the assumed economic drivers within the Hurunui case study.

The SRDM respondents identified that the primary drivers of afforestation were non-financial with a preference towards planting non-commercial forestry species. This is a variation from comparable studies that had placed a heavy weighting on the financial importance of afforestation. Ryan (2012) identified that farms with higher forestry income streams are likely to undertake afforestation and likely to consider forestry in the future. However, within this study, it was reported that 84% of farmers would not consider afforestation, regardless of the financial incentives. This result is similar to the SRDM respondents with future afforestation reported by only 29% of respondents regardless of the potential for higher returns relative to comparable land uses.

Smaill, Bayne, Coker, Paul, and Clinton (2014) identified that stakeholders in forestry are placing a higher importance in the ecosystem services and non-market values associated with forests. This study concluded that traditional market values would likely result in the planting of Pinus radiata in the majority of new forest areas. When comparing amenity value, bioenergy production, carbon capture, the diversity of native habitat, and erosion control/water quality, this study identified a significant interest in establishing species other than Pinus radiata in the belief that these alternative species are better suited to deliver these services. The primary planting drivers identified by SRDM respondents ranged from aesthetics, amenity, and landscape values through to providing habitat to increase biodiversity. The preference for native species by SRDM respondents is consistent with the belief that these alternative species are better suited to meet their drivers. Smaill et al. (2014) highlighted that a familiarity issue exists regarding existing tree species and that this needed to be addressed to improve the ecosystem services from planted forests. The drivers and species selection of the SRDM respondents indicates that they were not impacted by this familiarity issue given their preference being a shift away from the typical commercial forestry species.

The SRDM drivers of future planting were similar to the benefits of riparian planting identified by pastoral farmers (Maseyk, Dominati, White, & Mackay, 2017). The perceived benefits of this riparian planting were reported to be water quality, increased biodiversity, the provision of cultural ecosystem services, immediate direct benefits to farm management and the farm system, and in some instances increased productivity on-farm. These values align with the SRDM respondents' drivers and highlights a differing perspective to afforestation with landowners focusing on outcomes that are not purely financially driven.

When comparing similar research in which respondents self-identified as lifestyle farmers, it was identified that there was a common theme that lifestyle property owners were generally referred to as unproductive with low on-farm incomes. Within this study, lifestyle properties were categorised as per the AgriBase definition as an area of land between 0.4 ha–30 ha in total area (Asurequality, 2020). Lillis, Fairweather, & Sanson (2005) concluded that most smallholders intend to plant trees for landscaping or commercial purposes. Although these smallholders were engaged in agricultural production, it was identified that, in general, their actions focused on environmentally conscious activities as opposed to producing household income. This land use choice was further supported by smallholders identified to value peace and quiet, space and privacy, and clean air as opposed to prioritising income that supports their household. A similar result was observed within this study with both the drivers and species choice of lifestyle respondents' priorities being non-financial.

Research by Dhakal, Bigsby, and Cullen (2008) sought to understand the causes of land use change for plantation forestry and identify the key factors that drive the decision to plant areas of forestry. This study identified the predominant constraints for small landholders establishing plantation forestry as being principally financial. However, it was identified that this barrier could be overcome if smallholders had sufficient access to financial resources or a better understanding of taxation rules. This is consistent with the barriers to afforestation reported within the SRDM respondents, with 32% reporting a barrier being expense/financial. As identified by Dhakal, Bigsby, and Cullen (2008), it is likely that the SRMD respondents limited by expense/financial could overcome this barrier if they had better access to financial resources.

During the period that survey respondents indicated their future afforestation drivers, it is important to note that there was funding available under the One Billion Trees Programme (MPI, 2018). This programme focused on making it easier for landowners to integrate trees into their landscapes through direct landowner grants that provided direct access to a financial resource for tree planting. This funding provides an opportunity for landowners to overcome the financial barrier limiting plantation forestry previously identified. Just 6% of SRDM respondents reported funding under the One Billion Trees Programme fund as a driver of future afforestation indicating that access to financial resources is not driving afforestation within the Canterbury region. However, this is inconsistent with the results being reported in MPI (2020b) One Billion Trees Programme Fund 18 Month Monitoring and Evaluation Report. This report revealed a significant uptake in direct landowner grants in the Canterbury region with 13.8 million dollars of funding allocated over a three-year potential grant timeframe to projects based in Canterbury. This is a significant portion of the One Billion Trees Programme funding allocated to date (29%), demonstrating a strong uptake within the Canterbury region.

The species choice of the allocated funding significantly differs to the species preferences reported by SRDM respondents with 80% of the One Billion Trees funding in the Canterbury region classified as exotic tree species (Appendix C - Table 10).The results of the One Billion Trees Programme highlight that once the financial barrier limiting afforestation is overcome the majority of landowners in the Canterbury region chose to plant exotic tree species. However, the preference for planting exotic tree species is likely due to the funding amounts available for each species. Direct landowner grants could be applied to fund exotic planting at a base rate of $1,500/ha and indigenous mix planting at a base rate of $4,000/ha (Appendix C - Table 11). The exotic tree planting grant of $1,500 per hectare is observed to cover the majority of the cost of planting a commercial forestry species (Evison, 2008; Olssen et al., 2012). On the contrary, the native planting grant of $4,000 per hectare is significantly less than the reported cost of successfully establishing a native forest which is in the range of NZ$15,000–20,000 per hectare (Douglas, Dodd, and Power, 2007). The preference for exotic planting by applicants the One Billion Trees Programme highlights the effect of overcoming the financial barrier limiting afforestation reported by Dhakal et al. (2008). The impact of this is observed in the higher proportion of exotic trees funded given the financial barrier for afforestation can be overcome 100% for exotic planted compared to 25% for native planting.

4.3.4. Agent based modelling opportunity

Parker et al. (2003) suggested that Land-Uses and Land-Cover Changes models can be explained and simulated through the use of an agent-based model (ABM). An ABM can be used as an important resource to investigate landowners' behaviours and explore the interactions between the human agents and their environment (Matthews et al., 2007; O'Sullivan, 2008). Klosterman and Pettit (2005) summarise agent-based modelling as having the potential to categorise the behaviour of complex decisions by representing the behaviours of the agents within the system. In particular, the strengths of ABMs are described by Smajgl and Barreteau (2017) as having the capability to:

- "Model explicitly cognitive processes, human decision-making processes and social interactions,
- Model interactions between humans and technologies, the ecology, and physical dynamics,
- Spatially reference such cross-disciplinary interactions,
- Combine heterogeneous sources of knowledge, and - to link variables at variable resolutions across various scales."

Agent-based modelling provides a method to formalise the behaviour and cognitive processes of the agent who makes rural land use decisions. This element of analysis is important as personal, social and situation characteristics of rural landowners are identified as important determinants of behaviour rather than just profit maximisation which is generally assumed in more traditional land use change analysis (Derek T Robinson et al., 2007; Smithers & Furman, 2003). Profit maximisation was assumed when identifying the suitable plantable areas deemed economically superior to the next best alternative land use within the Hurunui case study. However, in contrast, the SRDM respondents identified that their primary drivers for afforestation were predominantly non-financial. The opportunity to create an ABM to simulate land use change based on landowners' behaviours would build upon the results of this study and expand the prediction of future afforestation within the Canterbury region. Additionally, with available data, an ABM could be expanded to model afforestation on a national scale.

The opportunity to create an ABM is dependent on suitable data being available. Ghorbani, Dijkema, and Schrauwen (2015) identified that quantitative data collected through interview-based surveys can provide rich data for building ABMs using an ethnography methodology. Ethnography is a research method in which data is gathered through interviews and field surveys which are then 'coded' for analysis. The interviewed subjects can be defined as agent types and analysed in a modelling framework such as the MAIA framework (Modelling Agent systems based on Institutional Analysis). The MAIA framework provides a guideline to arrive at a model of a social system defined by the following unrelated structures that group related concepts (Ghorbani, Dignum, Bots, & Dijkema, 2013):

- "In the Collective structure actors are defined as agents by capturing their characteristics and decision criteria based on their perceptions and goals."
- "The Constitutional structure defines roles and institutions. Actors can take multiple roles in social systems. These roles are formalised as unique sets of objectives and capabilities. Roles allow efficient modelling of heterogeneous agents who perform similar tasks."
- "The Physical structure is the non-social environment that the agents are embedded in its building blocks are physical components."
- "The Operational structure is viewed as an action arena where different situations take place, in which participants interact as they are affected by the environment. These produce outcomes that in turn affect the environment."
- "The Evaluative structure provides concepts with the help of which the modeller can indicate what patterns of interaction, evaluation, and outcomes she is interested in."

An adaption of the SRDM survey questions provides an opportunity to undertake data collection to capture coded interview data to build an ABM using the ethnography methodology. The data to build an ABM requires both quantitative and qualitative data (Yang & Gilbert, 2008). The SRDM would require amendments of questions specific to afforestation to capture more specific quantitative data. For example, this could be achieved through changes to the questions specific to past and future afforestation that quantifies the area of planting in hectares or as a percentage of total property size. Currently, the SRDM is undertaken using a web-based survey. However, a modification to the SRDM could be undertaken to capture coded data using an interview-based survey methodology. Changing to an in-person interview-based process is suggested to yield a higher response rate than the current web-based method. However, the costs incurred when collecting this data will be significantly higher as it requires trained enumerators to stimulate meaningful results (Balter et al., 2005; D. Brown et al., 2004; Couper, 2011; Manfreda et al., 2008; Shih & Fan, 2008).

An initial trail within the Hurunui TA would facilitate an initial expansion of this studies results. A trial ABM would provide a starting point for future research to implement this methodology on a larger scale while limiting the increased costs. Additionally, this would also allow a comparison between response rates recorded using the web-based survey and those interviewed in person. The response rate for the previous SRDM was identified as being lower than expected for web-based surveys. An in-person interview process may increase this response rate and potentially capture a more representative population of rural landowners.

When analysing land use and farmer behaviours, Mialhe, Becu, and Gunnell (2012) suggested using two basic agent types, farmers and investors. Investors agent’s behaviour could be modelled based on the assumption that they acquire new land at a required rate of return. The inputs for investor agents can be accessed from the Hunurui case study analysis and updated to reflect changes in assumptions. Consequently, the land that does not meet the required rate of return for investor driven land use change can be simulated for the farmer agents using interview driven SRDM data. Farmer agents could be classified as either “commercial” or “lifestyle” property owners to apply the results of the simulations based on agent property size and the opportunity for afforestation expansion. An ABM simulation provides an opportunity to model land use change based on agent behaviour instead of economic performance as per the Hurunui case study.

4.4. Conclusions

The Canterbury-based SRDM respondents represented a good spread across all TAs and included a wide range of property types. On the whole, respondents were weighted towards being an older male sample. This is consistent with being representative of New Zealand's farming population.

Analysis of the SRDM respondents identified the main drivers for afforestation were consistent for both historic and future planting activities. These drivers were identified as being primarily non-financial and prioritised drivers that had other positive impacts at a farm level. The single-most important drivers for future planting were also predominantly non-financial. The identification of a single most important driver also further highlighted that decision making considers the whole farm system. Respondents could not identify the most important driver of past planting. The respondents' inability to identify their primary driver likely represents the multiple considerations made during the decision-making process for undertaking afforestation.

When reporting properties as either lifestyle or commercial types, there was a clear trend that commercial properties placed a higher importance on the financial drivers than lifestyle properties. This trend was particularly seen in the potential for commercials properties to introduce carbon revenue through the NZ Emissions Trading Scheme. The main drivers remained unchanged for both commercial and lifestyle property owners, and non-financial drivers were the highest-ranked for both property types. However, financial drivers were identified to be ranked as more important for commercial property owners than their lifestyle property counterparts.

Non-commercial forestry species were the SRDM preferred species for future planting. The species selection aligns with the SRDM respondents' drivers and highlights belief that these alternative species are better suited to meet their drivers. Past research highlighted a familiarity issue limited landowners' preference for planting native trees. However, the results of this study indicate that the SRDM respondents were not impacted by this issue. A higher percentage of commercial property respondents reported a preference for planting commercial forestry species. This preference was observed to be driven by the Emission Trading Scheme carbon revenue instead of future harvest revenue.

The barriers to tree planting further supported the farm-level decision-making processes with opportunity cost identified as the number-one reason for not undertaking future planting. These respondents do not deem the financial benefits from afforestation sufficient to offset the decrease in farm income or the loss of utility from no longer farming the land. The financial barriers of planting trees were also identified as a dominant barrier. A portion of landowners were unwilling to plant trees based on the negative perception they had of the forestry industry. This represents a media-based barrier that is limiting future tree planting for these respondents.

Based on an agent analysis of survey respondents, it can be concluded that the landowners most likely to plant trees can be summarised as younger female lifestyle property owners. This agent type represents a minority of landowners within the rural sector and signals concerns about the expansion of the Canterbury plantation forestry estate.

The conclusions above represent the views of the respondents and the perspective they provide. Comparison to past research identified both confirmations and variations to the findings of this study. Consistent reporting of the perceived benefits of the non-market environmental farm-level advantages supported the main drivers of afforestation and consequent species choice. However, the drivers reported by SRDM respondents represent a different reality to what is currently occurring on rural land in Canterbury at present. The financial barriers to tree planting were observed to be overcome given the uptake in One Billion Tree Programme funding in the Canterbury region. With the ability to overcome financial barriers through the One Billion Trees Programme, a significant amount of land in Canterbury has been committed to planting exotic tree species. The greater area of exotic planting under the One Billion Trees Programme highlights that despite funding being available for native planting, this funding is not significant enough to overcome the financial barrier of planting native trees. Given the emphasis placed on non-financial drivers and non-commercial species, this barrier highlights the importance of the cost needing to be overcome for landowners to integrate trees that are not planted for profit.

Finally, through amendments to the SRDM survey questions and data collection process, the construction of an agent based model presents a future opportunity to expand this study's results. An ABM simulation could model land use change based on agent behaviour as opposed to just economic performance.

CHAPTER 5: SUMMARY OF CONCLUSIONS

Based on the analysis and results, the conclusions address the research questions and objectives outlined in Chapter 1.

5.1. Total area of land that could be planted as forestry in Canterbury

The first objective of this study was to determine the area of land that could be planted in forestry within the Canterbury region. The results of this study have identified that across all the Canterbury region, there are over 1.2 million hectares of land deemed suitable for afforestation from a biophysical point of view. The land suitable for afforestation represents a significant opportunity to expand the size of the Canterbury forestry area and consequently increase the future available wood supply.

5.2. Proportion of land that is economically superior to the next best alternative land use

The second objective of this study was to determine what proportion of this land is economically superior to the next best alternative land use if it is converted to forestry. The potential plantable area’s economic suitability was identified using the Hurunui case study and two criteria assumptions. Economically suitability was identified using the assumed rate of return on investment for forestry investment of 7% and the average economic return of the next best alternative land use, sheep and beef farming, 3.93%.

Within the Hurunui case study, 0% of the land suitable for afforestation achieved the forestry investment return requirement at the average land cost scenario. At the minimum land cost scenario, 4% of the total land suitable met the required rate of return for forestry investment-based afforestation. On an alternative land use basis, 82% the suitable planting areas within Hurunui TA provide an economic return that exceeded a typical sheep and beef farm return.

If these proportions were explicitly applied across the Canterbury region, then 50,945 ha would be attractive for an investor looking to establish commercial forestry, but only if they can acquire the land at the minimum cost. When compared to the alternative land use of sheep and beef farming, there are 1.04 million hectares of land within the Canterbury region that were deemed to economically superior to the next best alternative land use if planted in commercial forestry.

The influence of land cost, log price and carbon price significantly impacted the land deemed to be economically suitable for forestry. An increase in log price or carbon price either facilitates a higher land cost, increases the land deemed economically superior to the next best alternative land use, or a combination of both.

5.3. Drivers and barriers impacting afforestation

The third objective of this study was to determine the drivers and barriers that may impact the afforestation of the suitable land. A representative SRDM population identified that the main drivers for afforestation were non-financial for past and future planting and prioritised decisions that accounted for the farm-level impact of afforestation. The drivers for afforestation lead to a species selection for future planting that were primarily non-commercial forestry species. The drivers identified for afforestation and species choice were supported by previous research highlighting the perceived benefits of non-market, environmental and farm-level advantages achieved through afforestation. Carbon revenue, not harvest revenue, was observed to be the driver for the commercial property owners who selected commercial forest species for future planting.

The barriers to tree planting further supported a farm system-based decision-making process with consideration to the land's opportunity cost being the number one reason for not undertaking afforestation. It was also identified that the financial cost of undertaking tree planting was also a dominant barrier. The impact of overcoming this financial barrier was highlighted in the results of the One Billion Trees Programme funding. The afforestation trends through 1BT funding identified a bias towards the funding category in which this barrier was the most minimised—planting exotic tree species.

5.4. Potential future size of the Canterbury forestry area

The fourth objective was to combine the findings of this study to make a conclusion regarding the potential future size of Canterbury's planted forest area. These conclusions incorporate an expansion of the Hurunui cast study results to the wider Canterbury region combined with the drivers and barriers of afforestation.

A total of 4% of the land suitable for afforestation in the Hurunui TA met the required return requirement on a forestry investment basis. This represents a potential increase in the size of the Canterbury forestry area of 50,945 hectares. However, this assumes that all suitable land with a return suitable for forestry investment can be acquired as a discrete area of land by willing investors.

Assuming the current owners of rural land prioritised land use purely based on economic returns, 82% of the total land suitable for afforestation would be converted to forestry, a total of 1.04 million hectares. However, it is not reasonable to assume that all this area would be planted for forestry given the drivers of afforestation being primarily non-financial and prioritised non-commercial forestry species. The drivers for afforestation lead to commercial forestry species being selected for 14% of respondents future planting. Extrapolating the preference for commercial forestry species on the land deemed economically superior to the next best alternative land use results in a maximum potential expansion of the plantation forestry area of 146,212 hectares. However, this assumes that the 14% of respondents who identified commercial forestry species for future planting would commit 100% of their available land to forestry. Therefore, 146,212 hectares represents a maximum scenario for potential afforestation.

Combining the land likely to be afforested from a forestry investment perspective (50,945 ha) with the maximum area land likely to be afforested by rural landowners' (146,212 ha) it can be concluded that the size Canterbury plantation forestry area could increase by a maximum of 197,157 hectares. This increase represents an expansion of the current plantation forestry area in the Canterbury region by a multiple of 5x the area reported in the Wood Availability Forest. However, although this represents a significant increase compared to the current area of forestry, this increase represents just 15% of the hill country land (LUC 5, 6 & 7) in the Canterbury region.

The timeframe for this expansion to occur is unable to be accurately predicted. However, as an indication the One Billion Trees Programme funding of 6,409 hectares over a potential funding timeframe of 3 years represents an average expansion of 2,136 hectares per year during this period. At this rate, the time frame required to increase the plantation forest area's size by 197,157 hectares would be 92 years.

The potential for Canterbury’s plantation forestry estate to increase to 5x the current area presents an opportunity for an increase in the available wood supply within the region. However, this expansion relies on landowners overcoming their barriers to afforestation, and at the current planting rates, this expansion would gradually occur over a long-time horizon. An increase in available wood supply provides an opportunity for equivariant growth in the local domestic processing industry or export log industry.

5.5. Limitations and areas for further research

A limitation of this study is the assumption that the Hurunui case study data is applicable to the wider Canterbury region. An opportunity for further research exists to expand the methodology applied within the Hurunui case study to the other territorial authorities. This analysis would facilitate validation of the assumptions made within this study towards the expansion of the Hurunui case study. Additionally, further research that expands the case study to incorporate a broader geographic spread economic analysis presents an opportunity to compare economic returns for commercial forestry between TAs. This research should incorporate the marginal delivered cost curve analysis methodology applied within this study to identify the point at which an increasing marginal delivered cost may limit harvesting.

An expansion of this research presents an opportunity to collect interview-based survey data that can be used to construct an ABM to model. Given the increased cost of collecting the data, it could be incorporated within a future SRDM. Alternatively, this data collection could be undertaken as an independent study. Using this data, an agent-based afforestation model could predict land use change based on agent behaviour instead of purely economic land use assumptions. This research would build upon this study's results and provide an opportunity to model afforestation through time.

The conclusions drawn from the One Billion Trees funding granted provided an opportunity to explore the financial barrier being targeted through government funding and the place of non-commercial forestry species within these incentives. For further research, an opportunity exists that explores financial incentives for commercial forestry species and the necessary funding required to help landowners achieve their prioritised non-financial afforestation goals. Furthermore, the PCE Hurunui Case study identified that policy settings could significantly impact land use change to forestry. Further research is needed to explore the implications of specific policy changes that may increase or decrease afforestation. Additionally, policy settings could be identified and analysed to identify changes that would positively impact afforestation rates. The impact of varying policy settings could consequently be used as an input into an Agent Based Model.

Within this study, the media led perceptions about forestry were identified as being a barrier to tree planting for some respondents. An opportunity exists to further explore the interaction behind forestry’s social licence to operate and if this has the potential to limit future afforestation. As increasing social pressures mounts against traditional afforestation, the importance of this interaction presents an opportunity for future exploration. Additionally, this study identified landowners were planning future afforestation, but due to their individual drivers, selected non-commercial forestry species for future planting. Further research could explore the interaction behind forestry's social licence and the influence this has on species preference.

Given the significant area of land identified for afforestation, a research opportunity exists to explore the rate of afforestation further and identify strategies that can be implemented to increase the rate at which this occurs. This information could ultimately decrease the amount of time required to expand the Canterbury forestry estate by quantifying the current planting rate and an exploration of the improvements that increase the planting rate.

The conclusions of this study identified a potential to increase the Canterbury plantation forestry areas by 5x. This increase led to the suggestion that there was an opportunity to increase the domestic processing or log export industries to utilise the increased wood supply at harvest. An opportunity exists to undertake further research to identify the domestic processing industries that would be best suited for expansion within the Canterbury region.

Finally, the results of this research could be applied on a nationwide basis to explore afforestation opportunities in the whole of New Zealand. While the Canterbury region provides insight into the potential for the expansion of the forestry within this region, the methodology used within this study couple be applied to the broader New Zealand's rural landscape to conclude the potential for increased afforestation at a national level.

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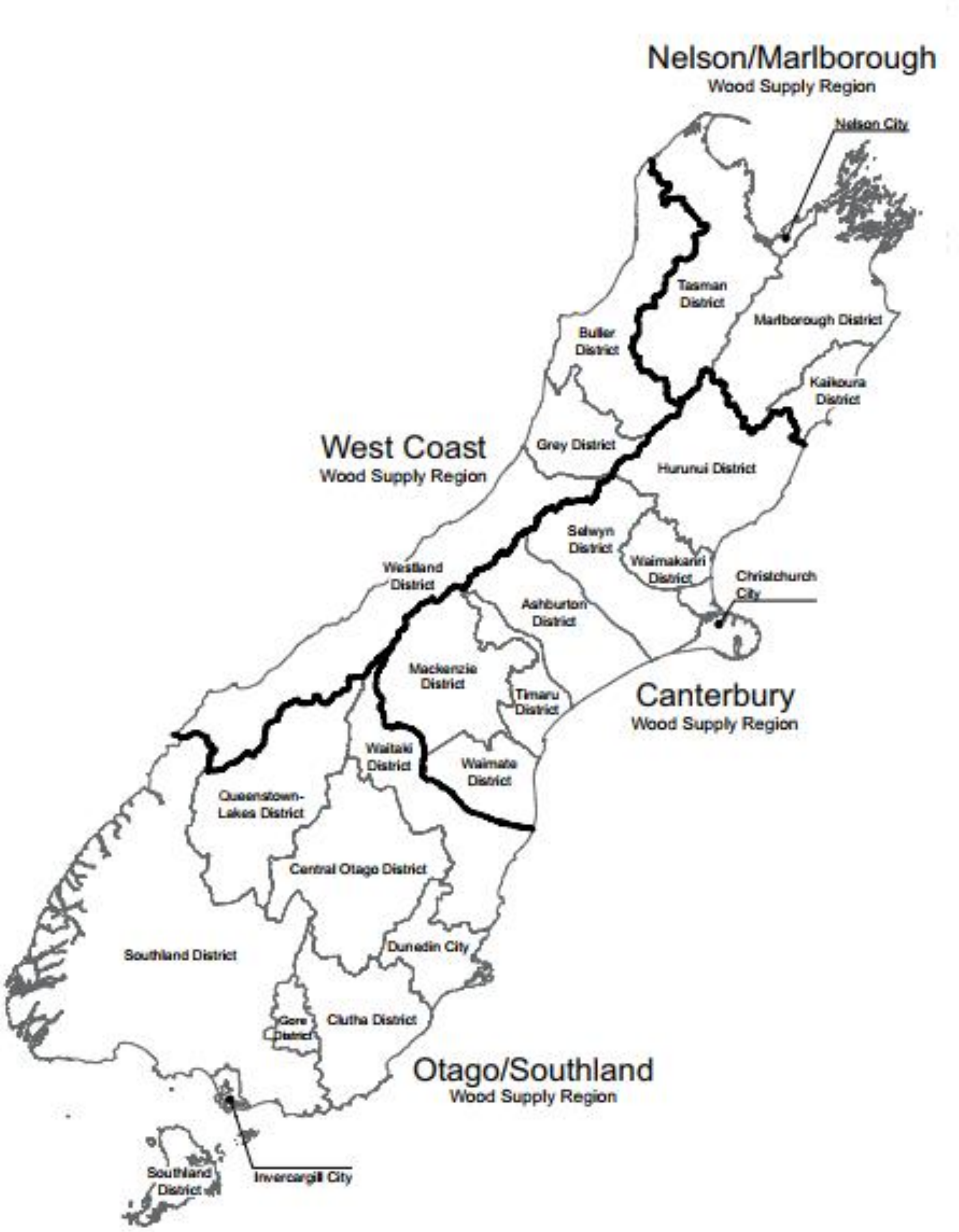
Appendices

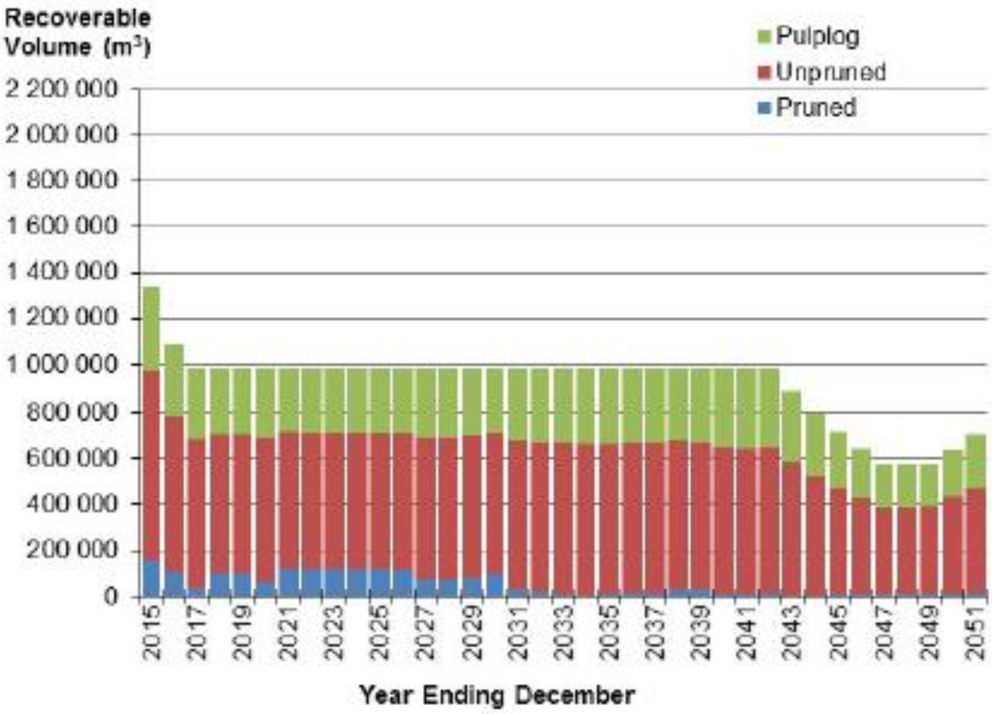
APPENDIX A: CHAPTER 1



Appendix A - Figure 1: Wood supply region boundaries (MPI, 2019b).

Appendix A - Table 1: Domestic processors operating in the Canterbury region in 2020

Sawn timber production level: 50 000–100 000 m3 per annum	
SRS New Zealand	*(Rolleston)*
Sawn timber production level: 25 000–49 999 m3 per annum	
McAlpines Sawmilling Ltd	*(Rangiora)*
McVicar Timber Group Ltd	*(Harewood)*
Sawn timber production level: 10 000–24 999 m3 per annum	
Mitchell Bros. Sawmillers	*(Darfield)*
Stoneyhurst Sawmilling Co. Ltd	*(Belfast)*
Sutherland Timber	*(Kaiapoi)*
Veneer and panel production level: 200,000 - 250,000 m3 per annum	
Daiken New Zealand	*(Rangiora)*



Appendix A - Figure 2: Canterbury Radiata Pine Availability under Scenario 2 - by Log Grade (MPI, 2016b)

Appendix A - Table 2: Canterbury roundwood removals by end market (%)
Source: Statistics New Zealand, Overseas Trade

Market	Percentage of total cut
Lyttelton port exports	31%
Timaru port exports:	22%
Domestic processing	46%
Total	**100%**

APPENDIX B: CHAPTER 3

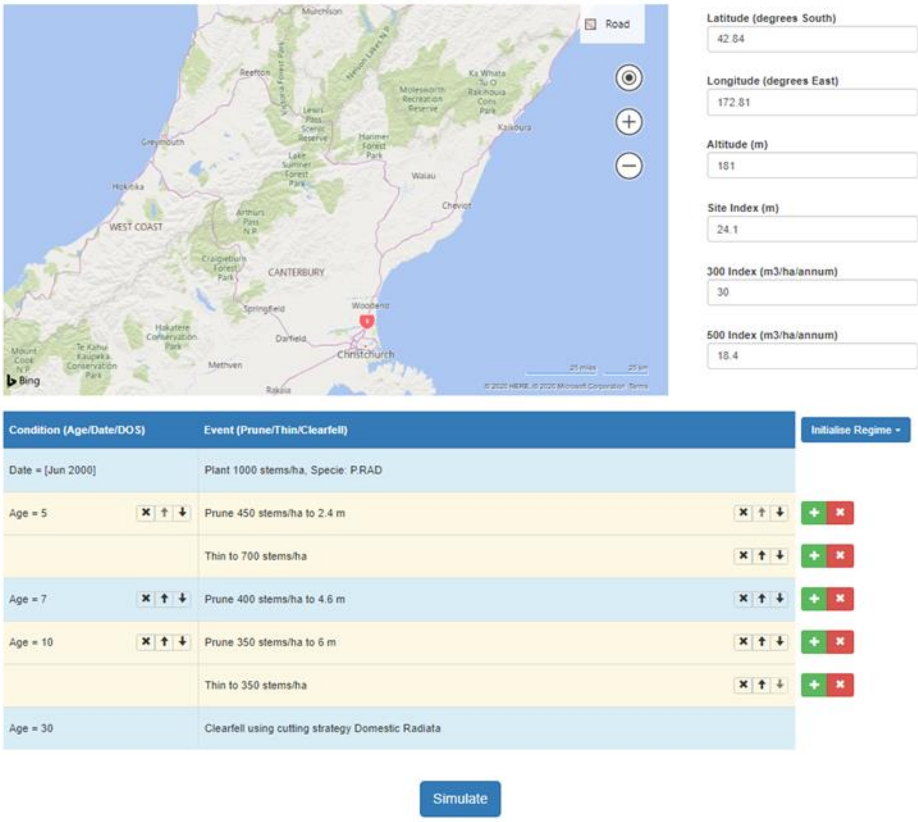
Appendix B - Table 1: Description of land use classes

Land-use class mapped		Land-use/Land cover sub-categories
FOREST LAND	Natural forest **LUC_ID = 71**	Areas that at 1 January 1990 were: • tall indigenous forest • self-sown exotic trees such as wilding conifers and grey willows established before 1 January 1990 • broadleaved hardwood shrubland, manuka/kanuka shrubland and other woody shrubland (≥ 30 per cent cover, with potential to reach ≥ 5 m at maturity in situ under current land management within 30–40 years) • areas of bare ground of any size which were previously forested but, due to natural disturbances (eg, erosion, storms, fire) have lost vegetation cover • roads/tracks less than 30 m width within the above categories and areas which subsequently meet the above criteria on land which was forest land at 1990 (classed as Natural forest or Pre-1990 planted forest at 1990).
	Pre-1990 planted forest **LUC_ID = 72**	• radiata pine, Douglas-fir, eucalypts or other planted species (with potential to reach ≥ 5 m height at maturity in situ) planted before 1 January 1990, or replanted on land which was forest land as at 31 December 1989 • exotic forest species that were planted after 31 December 1989 into land that was natural forest • riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 • harvested areas within pre-1990 forest land (assumes these will be replanted, unless deforestation is later detected) • includes roads/tracks/skid sites/other temporarily un-stocked areas within forest that are less than the minimum area of 5 ha or width of 30 m • areas of bare ground of any size which were previously forested at 31 December 1989 but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover
	Post-1989 forest **LUC_ID = 73**	• exotic forest (with the potential to reach ≥ 5 m height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (eg, radiata pine, Douglas-fir, eucalypts or other planted species) • harvested areas within post-1989 forest land (assumes these will be replanted, unless deforestation is later detected) • forests arising from natural regeneration of indigenous tree species as a result of land management change after 31 December 1989
		• self-sown exotic trees such as wilding conifers or grey willows established after 31 December 1989 • riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • includes roads/tracks/skid sites/other temporarily un-stocked areas within the forest that are less than the minimum area of 5 ha or width of 30 m • areas of bare ground of any size which were previously forested (established after 31 December 1989) but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover.

GRASSLAND	**Grassland – with woody biomass** **LUC_ID= 74**	• grassland with matagouri and sweet briar, broadleaved hardwood shrubland, manuka/kanuka shrubland, coastal and other woody shrubland (< 5 m tall and any per cent cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30–40 year time period • above timberline shrubland vegetation and intermixed with montane herbfields (does not have the potential to reach > 5 m height *in situ*) • grassland with tall tree species (< 30 per cent cover), such as golf courses in rural areas (and except where the Land Cover Databases (LCDB1 and LCBD2) have classified these as settlements) • grassland with riparian or erosion control plantings (< 30 per cent cover) • linear shelterbelts that are > 1 ha in area and >30 m mean width • areas of bare ground of any size which previously contained grassland with woody biomass but, due to natural disturbances (eg, erosion, fire) have lost vegetation cover
GRASSLAND	Grassland – high producing **LUC_ID = 75**	• grassland with high quality pasture species • includes linear shelterbelts which are <1 ha in area or <30 m mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • areas of bare ground of any size which were previously grassland but, due to natural disturbances (eg, erosion) have lost vegetation cover
GRASSLAND	Grassland – low producing **LUC_ID = 76**	• low fertility grassland and tussock grasslands • mostly on hill country • montane herbfields at either an altitude higher than above timberline vegetation or where the herbfields are not mixed up with woody vegetation • includes linear shelterbelts which are <1 ha in area or <30 m mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • other areas of limited vegetation cover and significant bare soil including erosion and coastal herbaceous sand dune vegetation
CROPLAND	Cropland – perennial **LUC_ID = 77**	• all orchards and vineyards • linear shelterbelts associated with perennial cropland
CROPLAND	Cropland – annual **LUC_ID = 78**	• all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland
WETLAND	Wetland – open water **LUC_ID = 79**	• all open water ie, lakes, rivers, dams, reservoirs, estuaries (where within the defined coastline of New Zealand)
WETLAND	Wetland – vegetated non forest **LUC_ID = 80**	• herbaceous and/or non-forest woody vegetation periodically flooded. Scattered patches of tall tree-like vegetation of <30% cover to be included as wetlands • estuarine/tidal areas including mangroves
SETTLEMENTS	Settlements **LUC_ID = 81**	• built-up areas and impervious surfaces • grassland within settlements including recreational areas, urban parklands and open spaces which do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction
OTHER LAND	Other **LUC_ID = 82**	• montane rock/scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, eroded gullies with no vegetation, mines (including spoil), quarries • permanent ice/snow and glaciers • any other remaining land that does not fall into any of the other land-use categories.

Appendix B - Table 2: Hurunui case study static forecaster inputs

Hawarden	Hurunui, New Zealand
Latitude	42.84 South
Longitude	172.81 East
Altitude	181.00m



Appendix B - Figure 1: Forecaster Calculator's silvicultural regime for a clearwood regime

Appendix B - Table 3: Canterbury region hill country property recent sales evidence (Colliers, 2020)

Property	Sale Date	Area (ha)	SU/ha	Net sale price (NSP)	NSP/ha
1579P Ram Paddock Rd, Broomfield	Sep-19	81	3.5	$255,000	$3,148
441 Blythe Rd, Motunau	Apr-20	1,242.7	3.5	$4,500,000	$3,621
1135P Leader Rd West, Waiau	Feb-20	339.2	5.2	$925,000	$2,727
884 Riverview Rd, Domett	Dec-19	543.8	3.3	$2,300,000	$4,229
283 McRaes Rd, Scargill	Apr-20	731	5.2	$4,200,000	$5,746
123 Glenkens Rd, Cheviot	Mar-18	705	5.8	$3,800,000	$5,390
338 Birchdale Road. Masons Flat	Nov-19	660.4	5.1	$4,901,000	$7,421
1007 Motunau Beach Rd, Motunau	Aug-19	269.2	6	$2,250,000	$8,358
554 Waikari Valley Rd, Scargill	Jan-20	637.6	6.6	$4,725,000	$7,411
1108 Happy Valley Road, Motunau	Mar-18	513.4	6.7	$3,950,000	$7,694
				Average (NSP/ha)	**$5,575**

Appendix B - Table 4: LUCAS classification of underlying LUC class 5, 6 and 7 land for Hurunui, Selwyn, Waimakariri and Christchurch TAs

LUCAS Classification	Hurunui	Selwyn	Waimakariri	Christchurch
Cropland - Annual	1,268	307	187	236
Cropland - Perennial	20	0	23	86
Grassland - High producing	37,322	5,323	4,259	15,405
Grassland - Low producing	218,208	87,906	22,811	47,856
Grassland - With woody biomass	43,957	16,108	6,204	14,336
Other	131	2,730	147	170
Settlements	43	12	446	2,650
Wetland - Open water	383	1,061	205	167
Wetland - Vegetated non forest	42	1,902	184	746
Total	**301,374**	**115,349**	**34,468**	**81,651**

Appendix B - Table 5: LUCAS classification of underlying LUC class 5, 6 and 7 land for Ashburton, Timaru, Mackenzie and Waimate TAs

LUCAS Classification	Ashburton	Timaru	Mackenzie	Waimate
Cropland - Annual	149	561	1,048	844
Cropland - Perennial	0	0	0	0
Grassland - High producing	5,501	14,879	11,776	25,765
Grassland - Low producing	116,179	44,477	318,392	145,439
Grassland - With woody biomass	8,555	6,467	11,319	6,554
Other	3,758	853	4,386	281
Settlements	9	18	486	4
Wetland - Open water	286	66	3,366	386
Wetland - Vegetated non forest	3,095	148	3,808	66
Total	**137,531**	**67,468**	**354,581**	**179,339**

Appendix B - Table 6: DWC inputs for the suitable planting areas within the Hurunui TA

Harvesting Costs	Min	Max	Mean
Total contiguous forest area (ha)	1	7,142	220
Expected volume per hectare (t/ha)	272	877	660
Average slope of terrain in %	0	53	20
# Log Sorts		11	

Roading Cost (access to harvest area)	Min	Max	Mean
Meters of new road in hilly to steep terrain	0	157,131	4,790
Meters of new road in flat to rolling terrain	0	6,223	42
Meters of existing road needing improvement		0	
Fee for road maintenance (Yes, No)		Yes	
Number of landings (approximately 1 for every 6-8 ha.)	0	1,190	37

Transportation Costs (forest to mill or port)	Min	Max	Mean
Kilometers to be travelled on forest / unsealed road	0.0	157.1	4.8
Kilometres to be travelled on sealed public road	52.5	194.8	120.4

APPENDIX C: CHAPTER 4

Appendix C - Table 1: Survey of Rural Decision Makers questions of interest

Farm descriptions

Q10 Which situation best applies to your land?
Remember to click the right arrow after you have made your selection.

- Commercial farming/forestry
- Lifestyle farming/forestry
- Farming/forestry that is not quite commercial and not quite lifestyle
- Other agricultural industry

Q13 Which of the following best describes your primary role on the farm?
Why do we need to know your primary role?

We'd like to know your primary role on the farm because some of the later questions in the survey only apply to owners, some only apply to partners, some only apply to managers, some only apply to trusts, etc.

- Farm owner/joint-farm owner
- Equity partner/partnership
- Farm manager/operations manager/supervisor/CEO/etc.
- Share milker
- Representative of a Māori trust/incorporation
- Representative of a family trust or other trust
- Leasee
- Other (please specify)

Q22 In which region and district is your farm located?
If your farm spans multiple regions/districts, please indicate the region and district of the largest area (whether a single block or many blocks).

- Region
- District

Q23 In which region and district is your second largest land parcel by area (whether a single block or many blocks) located?

- Region
- District

Q24 In which region and district is your third largest land parcel by area (whether a single block or many blocks) located?

- Region
- District

Q28 On 30 June 2019, what was the total area of the farm, including run-offs and land leased from others, in hectares?
For reference, 1 hectare = 2.5 acres. Please don't count land leased to others or used by others.

Total area (hectares)	
Of which, amount leased from others, if any (hectares)	

Q29 Which of the following land uses apply to the land that you actively managed during the previous 12 months?
Tick all that apply.

Grazing livestock that are NOT OWNED by the farming business (e.g. dairy support)	
Farming sheep and/or beef	
Raising and/or finishing prime cattle, including bull beef	
Operating a dairy platform	
Operating a dairy run off	
Raising deer	
Raising pigs	
Raising poultry birds	
Raising other farmed livestock (e.g. horses, goats, ostriches and emus, alpacas and llamas)	
Growing grain and seed crops	
Growing crops for hay, silage, or balage	
Growing vegetables and/or cooking herbs INDOORS	
Growing vegetables and/or cooking herbs OUTDOORS	
Growing flowers, bulbs, nursery crops, and hops	
Growing kiwifruit	
Growing wine grapes	
Growing other fruits, nuts, and edible tree crops	
Exotic forest intended for commercial harvest	
Harvested exotic forest area awaiting restocking	
Native forest intended for commercial timber harvest	
Native forest/bush for commercial harvest of non-timber products (e.g. oils, honey)	
Farm-based tourism	
Beekeeping for honey harvest	

Q30 In [district = Canterbury], which activity do you consider to be your primary activity?
Which is your secondary activity (if any)?

Primary activity	▼ Grazing livestock that are not owned by the farming business
Secondary activity	▼ Grazing livestock that are not owned by the farming business

Participant existing forestry information

Q34 On 30 June 2019, what was the area of the farm allocated to the following, in hectares?
For reference, 1 hectare = 2.5 acres.
Please don't count land leased to others or used by others.

Exotic forest intended for commercial harvest	
Exotic forest awaiting restocking	
Native forest for intended commercial timber harvest	
Native forest/bush for commercial harvest of non-timber products	
Native bush that won't be used commercially (apart from firewood)	
Wetlands	

Other land that is not used for grazing, growing crops, or forestry

Q57 When was your land first planted in forest?
Please indicate the percentage of your total forestry according to when it was planted. Enter the percentage as a number, e.g. 20% should be entered as 20. The column should total 100%.

- First planted before 1 January 1990 : _______
- First planted after 31 December 1989 : _______
- Total : ________

Q58 Is all or part of your post-1989 forest registered in the Emissions Trading Scheme (ETS)?

- Yes
- No
- Unsure

Q63 When will you next harvest all or part of this forest?

- Continuous harvest
- Within 2 years
- Within 3-5 years
- Within 5-10 years
- More than 10 years from now
- Unsure

Q64 Do you currently plan to replant after harvesting?

- Yes
- No
- Unsure

Q65 Which is the main reason that you do not plan to replant?

- Uncertainty in timber prices
- Uncertainty in ETS
- Harvest time too far off in the future
- Other land uses have higher returns
- Increased regulatory complexity
- Decision taken by investors as a group
- Never intended to replant
- Retirement / plan to stop working
- Other (please specify)

Afforestation Drivers

Q99 This part of the survey focuses on tree planting and management.
Has the total amount of land planted in trees (net stocked forest area) on your farm in [district = Canterbury] increased in the recent past? Will it increase in the near future?

	Yes	No	Unsure
Increased within the last 10 years			
Will increase in next 2 years			

Q100 Which of the following are the main reasons for your decision to plant trees on your farm in [district = Canterbury] in the recent past?
Select all that apply.

- Potential for future harvest
- Carbon credits/ Emissions Trading Scheme
- Funding under the One Billion Trees Fund
- Funding schemes other than One Billion Trees
- Provide habitat to increase biodiversity
- Increase resilience to changing climate
- Promote human health
- Promote livestock health (shelter, shade, fodder)
- Guardianship / kaitiaki
- Control erosion
- Promote water quality
- Aesthetics, amenity, and landscape values
- Offset farm emissions
- Personal wellbeing, spiritual or cultural values
- Succession planning
- Firewood, posts, and farm timbers
- Coordinated with neighbours to have a large forested area
- Create employment opportunities
- Other (please specify below)
- Unsure

Q101 Among the main reasons for the decision to plant trees on your farm in [district = Canterbury] in the recent past, which was the single most important?

- Potential for future harvest
- Carbon credits/ Emissions Trading Scheme
- Funding under the One Billion Trees Fund
- Funding schemes other than One Billion Trees
- Providing habitat to increase biodiversity
- Increase the farm's resilience to changing climate
- Promote human health
- Promote livestock health
- Guardianship / kaitiaki
- Control erosion
- Promote water quality
- Aesthetics, amenity, and landscape values
- Offset farm emissions
- Personal wellbeing, spiritual or cultural values
- Succession planning
- Firewood, posts, and farm timbers
- Coordinated with neighbours to have a large forested area
- Create employment opportunities

Q102 Of the land that you intend to plant trees in [district = Canterbury] over the next 2 years, what % of the total area do you expect to plant with each of the following types of trees?
Enter the percentage as a number, e.g. 20% should be entered as 20. The column should total 100%.

- Radiata pine : _______
- Douglas fir : _______
- Other exotic conifers : _______
- Other exotic trees (e.g. poplar, willow, oak, eucalypts) : _______
- Mānuka and kānuka : _______
- Other native species : _______
- Undecided : _______
- Total : ________

Q103 Which of the following are the main reasons for your decision to plant trees on your farm in [district = Canterbury] in the next two years?
Select all that apply.

- Potential for future harvest
- Carbon credits/ Emissions Trading Scheme
- Funding under the One Billion Trees Fund
- Funding schemes other than One Billion Trees
- Provide habitat to increase biodiversity
- Increase resilience to changing climate
- Promote human health
- Promote livestock health (shelter, shade, fodder)
- Guardianship / kaitiaki
- Control erosion
- Promote water quality
- Aesthetics, amenity, landscape values
- Offset farm emissions
- Personal wellbeing, spiritual or cultural values
- Succession planning
- Firewood, posts, and farm timbers
- Coordinated with neighbours to have a large forested area
- Create employment opportunities
- Other (please specify below)
- Unsure

Q104 Among the main reasons of the decision to plant trees on your farm in [district = Canterbury], which is the single most important?

- Potential for future harvest
- Carbon credits/ Emissions Trading Scheme
- Funding under the One Billion Trees Fund
- Funding schemes other than One Billion Trees
- Providing habitat to increase biodiversity
- Increase the farm's resilience to changing climate
- Promote human health
- Promote livestock health
- Guardianship/kaitiaki
- Control erosion
- Promote water quality
- Aesthetics, amenity, landscape values
- Offset farm emissions
- Personal wellbeing, spiritual or cultural values
- Succession planning
- Firewood, posts, and farm timbers
- Coordinated with neighbours to have a large forested area
- Create employment opportunities

Q105 Could your land and commercial enterprise potentially accommodate planting new land in trees if you decided to in the future?

- Yes
- No
- Unsure

Q106 What are the main reasons that you do not plan to plant new land in trees in [district = Canterbury] in the short-medium term? Select all that apply.

- Expense / financial barriers
- Labour needed to plant and maintain trees
- Uncertainty about best land use options
- Negative perceptions about tree planting / forestry
- Opportunity cost / better uses for land
- Other (please describe)
- None of the above

Q107 Are you familiar with financial support available for tree planting on private land under the One Billion Trees programme?

- Yes
- No
- Unsure

Additional Potential Afforestation Drivers

Q112 This part of the survey focuses on climate in Aotearoa New Zealand.
There has been a lot of discussion about climate change in the media. Which of the following statements best describes your personal thoughts about climate change?

- Climate change is already affecting New Zealand
- Although climate change is not yet affecting New Zealand, it will in the next 10 years
- Although climate change will not affect New Zealand in the next 10 years, it will in the future
- Climate change will not affect New Zealand
- Unsure

Respondent descriptions

Q152 The questions in this section are about your personal background.
What is your gender?

Your gender	▼ Male... Prefer not to answer
Your spouse / partner's gender	▼ Male... Prefer not to answer

Q153 What is your birth year?

Your birth year	▼ Prefer not to answer... 1919
Your spouse / partner's birth year	▼ Prefer not to answer... 1919

Q154 How many years of on-farm experience after the age of 18 do you have?

- Years of experience (yourself) ________________________
- Years of experience (spouse/partner) ______________________

Q155 How many generations has your family farmed in Aotearoa New Zealand?

Your family	▼ 1... Unsure / Prefer not to answer
Your spouse / partner's family	▼ 1... Unsure / Prefer not to answer

Q156 What is your ethnicity?
Tick all that apply.

	Yourself	Your spouse / partner
New Zealand European		
Māori		
Chinese		
Indian		
Samoan		
Cook Island Maori		
Tongan		
Niuean		
Other European (e.g. British)		
Other (please specify)		
Prefer not to answer		

Appendix C - Table 2: SRDM respondents identified drivers for afforestation within the past 10 years

Past planting (Drivers)		
	Count	**% of total**
Land in trees increased within the last 10 years	177	32%
Drivers	**Count**	**% of total**
Aesthetics, amenity, and landscape values	46	26%
Promote livestock health (shelter, shade, fodder)	38	21%
Provide habitat to increase biodiversity	29	16%
Personal wellbeing, spiritual or cultural values	23	13%
Firewood, posts, and farm timbers	20	11%
Potential for future harvest	17	10%
Increase resilience to changing climate	15	8%
Guardianship / kaitiaki	12	7%
Control erosion	11	6%
Promote human health	9	5%
Promote water quality	9	5%
Offset farm emissions	9	5%
Carbon credits/ Emissions Trading Scheme	7	4%
Succession planning	7	4%
Other	4	2%
Coordinated with neighbours to have a large forested area	3	2%
Funding under the One Billion Trees Fund	1	1%
Create employment opportunities	1	1%
Funding schemes other than One Billion Trees	0	0%
Unsure	0	0%

Appendix C - Table 3: Commercial property SRDM respondents identified drivers for afforestation within the past 10 years

Past planting (Drivers) - Commercial		
	Count	**% of total**
Land in trees increased within the last 10 years	62	35%
Drivers	**Count**	**% of total**
Aesthetics, amenity, and landscape values	18	29%
Promote livestock health (shelter, shade, fodder)	16	26%
Provide habitat to increase biodiversity	12	19%
Control erosion	9	15%
Potential for future harvest	8	13%
Guardianship / kaitiaki	8	13%
Promote water quality	8	13%
Personal wellbeing, spiritual or cultural values	7	11%
Carbon credits/ Emissions Trading Scheme	6	10%
Offset farm emissions	6	10%
Succession planning	6	10%
Increase resilience to changing climate	5	8%
Firewood, posts, and farm timbers	4	6%
Promote human health	2	3%
Other	2	3%
Funding under the One Billion Trees Fund	1	2%
Funding schemes other than One Billion Trees	0	0%
Coordinated with neighbours to have a large forested area	0	0%
Create employment opportunities	0	0%
Unsure	0	0%

Appendix C - Table 4: Lifestyle property SRDM respondents identified drivers for afforestation within the past 10 years

Past planting (Drivers) - Lifestyle		
	Count	**% of total**
Land in trees increased within the last 10 years	102	58%
Drivers	**Count**	**% of total**
Aesthetics, amenity, and landscape values	28	27%
Promote livestock health (shelter, shade, fodder)	22	22%
Provide habitat to increase biodiversity	17	17%
Firewood, posts, and farm timbers	16	16%
Personal wellbeing, spiritual or cultural values	16	16%
Increase resilience to changing climate	10	10%
Potential for future harvest	8	8%
Promote human health	7	7%
Guardianship / kaitiaki	4	4%
Coordinated with neighbours to have a large forested area	3	3%
Offset farm emissions	3	3%
Control erosion	2	2%
Create employment opportunities	1	1%
Other	1	1%
Carbon credits/ Emissions Trading Scheme	1	1%
Succession planning	1	1%
Promote water quality	1	1%
Funding schemes other than One Billion Trees	0	0%
Unsure	0	0%
Funding under the One Billion Trees Fund	0	0%

Appendix C - Table 5: SRDM respondents identified most important driver for afforestation within the past 10 years

Past planting (Most important driver)		
	Count	**% of total**
Land in trees increased within the last 10 years	177	32%
Most important ranking	**Count**	**% of total**
No response	116	66%
Aesthetics, amenity, and landscape values	21	12%
Providing habitat to increase biodiversity	9	5%
Potential for future harvest	7	4%
Promote livestock health	7	4%
Other	4	2%
Control erosion	3	2%
Increase the farm's resilience to changing climate	2	1%
Promote water quality	2	1%
Personal wellbeing, spiritual or cultural values	2	1%
Firewood, posts, and farm timbers	2	1%
Offset farm emissions	1	1%
Create employment opportunities	1	1%
Carbon credits/ Emissions Trading Scheme	0	0%
Funding under the One Billion Trees Fund	0	0%
Funding schemes other than One Billion Trees	0	0%
Promote human health	0	0%
Guardianship / kaitiaki	0	0%
Succession planning	0	0%
Coordinated with neighbours to have a large forested area	0	0%

Appendix C - Table 6: SRDM respondents identified drivers for afforestation within the next 2 years

Future planting (Drivers)		
	Count	**% of total**
Land in trees will increase within the next 2 years	161	29%
Drivers	**Count**	**% of total**
Aesthetics, amenity, and landscape values	107	66%
Promote livestock health (shelter, shade, fodder)	105	65%
Provide habitat to increase biodiversity	103	64%
Personal wellbeing, spiritual or cultural values	72	45%
Promote water quality	66	41%
Guardianship / kaitiaki	61	38%
Firewood, posts, and farm timbers	49	30%
Increase resilience to changing climate	44	27%
Control erosion	44	27%
Promote human health	38	24%
Potential for future harvest	32	20%
Offset farm emissions	26	16%
Succession planning	20	12%
Carbon credits/ Emissions Trading Scheme	16	10%
Funding under the One Billion Trees Fund	9	6%
Coordinated with neighbours to have a large forested area	6	4%
Other	4	2%
Funding schemes other than One Billion Trees	1	1%
Create employment opportunities	2	1%
Unsure	0	0%

Appendix C - Table 7: Commercial property SRDM respondents identified drivers for afforestation within the next 2 years

Future planting (Drivers) - Commercial		
	Count	**% of total**
Land in trees will increase within the next 2 years	55	34%
	Count	**% of total**
Aesthetics, amenity, and landscape values	38	61%
Provide habitat to increase biodiversity	35	56%
Promote livestock health (shelter, shade, fodder)	32	52%
Promote water quality	31	50%
Guardianship / kaitiaki	22	35%
Control erosion	22	35%
Personal wellbeing, spiritual or cultural values	21	34%
Offset farm emissions	17	27%
Increase resilience to changing climate	15	24%
Carbon credits/ Emissions Trading Scheme	11	18%
Potential for future harvest	10	16%
Succession planning	10	16%
Firewood, posts, and farm timbers	9	15%
Promote human health	8	13%
Funding under the One Billion Trees Fund	7	11%
Coordinated with neighbours to have a large forested area	3	5%
Create employment opportunities	1	2%
Other	1	2%
Funding schemes other than One Billion Trees	0	0%
Unsure	0	0%

Appendix C - Table 8: Lifestyle property SRDM respondents identified drivers for afforestation within the next 2 years

Future planting (Drivers) - Lifestyle		
	Count	**% of total**
Land in trees will increase within the next 2 years	86	53%
		% of total
Promote livestock health (shelter, shade, fodder)	58	57%
Aesthetics, amenity, and landscape values	53	52%
Provide habitat to increase biodiversity	51	50%
Personal wellbeing, spiritual or cultural values	39	38%
Firewood, posts, and farm timbers	34	33%
Guardianship / kaitiaki	25	25%
Promote water quality	26	25%
Promote human health	21	21%
Potential for future harvest	18	18%
Increase resilience to changing climate	16	16%
Control erosion	14	14%
Succession planning	9	9%
Offset farm emissions	6	6%
Coordinated with neighbours to have a large forested area	3	3%
Carbon credits/ Emissions Trading Scheme	3	3%
Other	2	2%
Funding under the One Billion Trees Fund	2	2%
Funding schemes other than One Billion Trees	1	1%
Create employment opportunities	1	1%
Unsure	0	0%

Appendix C - Table 9: SRDM respondents identified most important driver for afforestation within the next 2 years

Future planting (Drivers)		
	Count	**% of total**
Land in trees will increase within the next 2 years	161	29%
Most important ranking	**Count**	**% of total**
Providing habitat to increase biodiversity	34	21%
Aesthetics, amenity, and landscape values	25	16%
Promote livestock health	21	13%
Guardianship / kaitiaki	20	12%
No response	15	9%
Increase the farm's resilience to changing climate	9	6%
Potential for future harvest	8	5%
Firewood, posts, and farm timbers	8	5%
Personal wellbeing, spiritual or cultural values	6	4%
Promote water quality	5	3%
Control erosion	4	2%
Promote human health	2	1%
Offset farm emissions	2	1%
Carbon credits/ Emissions Trading Scheme	1	1%
Succession planning	1	1%
Funding under the One Billion Trees Fund	0	0%
Funding schemes other than One Billion Trees	0	0%
Coordinated with neighbours to have a large forested area	0	0%
Create employment opportunities	0	0%

Appendix C - Table 10: One Billion Trees Programme direct landowner grants regional breakdown (MPI, 2020b)

Direct Landowner Grants regional breakdown						
Region	Number of approved grants	Funding allocated ($)	Indigenous trees funded	Exotic trees funded	Indigenous planting area (hectares)	Exotic planting area (hectares)
Auckland	21	830,103	692,666	2,104	202	2
Bay of Plenty	30	1,151,300	542,385	70,804	256	74
Canterbury	86	13,755,020	858,413	5,779,011	1,558	6,409
Chatham Islands	1	856,635	154,198	11,407	140	10
Gisborne	17	1,714,361	701,188	422,660	309	342
Hawke's Bay	58	7,209,974	2,907,700	1,456,090	2,152	1,487
Manawatū/Whanganui	32	4,939,863	2,915,665	295,871	1,938	302
Marlborough	15	2,778,723	612,537	799,456	371	832
Multi-Region	2	349,565	125,068	0	77.83	0
Northland	42	2,403,491	774,207	399,246	420	359
Otago	52	3,407,822	562,525	1,878,403	228	1,726
Southland	30	1,906,800	218,622	737,376	199	660
Taranaki	8	1,351,967	455,229	207,922	485	204
Tasman	16	1,630,850	83,060	833,303	89	791
Waikato	35	968,320	500,295	130,218	195	147
Wellington	18	1,849,294	388,836	523,691	232	559
West Coast	3	75,500	4,151	26,430	4	32
Grand total	**466**	**47,179,587**	**12,496,745**	**13,573,992**	**8,858**	**13,936**

Appendix C - Table 11: One Billion Trees Programme direct landowner grants (MPI, 2018)

			Top-up available/hectare		
Type of planting	Size	Base rate/hectare	Erosion prone land OR land in areas that support regional development goals	Fencing	Ecological restoration partnership projects (see p.9)
Indigenous mix (e.g. a mix of native trees and shrubs)	1 – 300 hectares	$4000	$500	Up to $500	Up to $2000
Mānuka/kānuka (particularly for erosion control or as a nurse crop for an indigenous forest)	5 – 300 hectares	$1800	$500	NA	NA
Indigenous natural regeneration (e.g. retiring land and managing it to naturally return back to trees)	5 – 300 hectares	$1000	$500	Up to $500	NA
Exotic (e.g. planting eucalypts, redwoods or pinus radiata to stabilise erosion-prone land)	5 – 300 hectares	$1500	$500	NA	NA